

**BBC** FLYING WITHOUT FOSSIL FUELS THE ION DRIVE TAKES OFF

# FOCUS

SCIENCE | TECHNOLOGY | HEALTH

## RADICAL IDEAS TO EXPAND YOUR MIND



DIETS MAKE  
YOU FAT

A MAGIC NUMBER  
RULES THE UNIVERSE

EVOLUTION NEEDS  
OUR HELP

THE REAL YOU  
ISN'T REAL

MICROBES CHANGE  
THE WEATHER

DYING ISN'T AS BAD  
AS YOU THINK

### EARTH'S HIDDEN OCEANS

Digging into the strange world  
beneath our feet

### SCIENCE OF BRAIN TINGLES

Why ASMR helps people relax and  
how we can use it for therapy

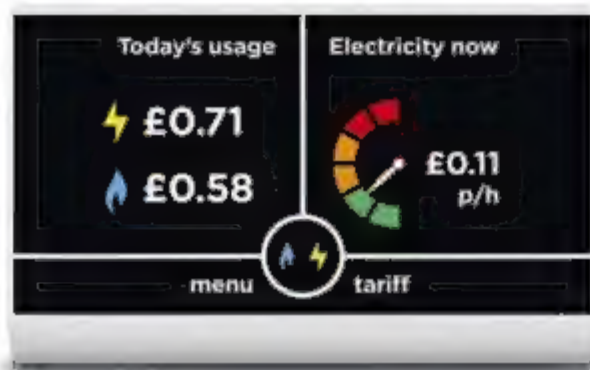
### BEATING ADDICTION

How MDMA could help alcoholics  
break their dependency

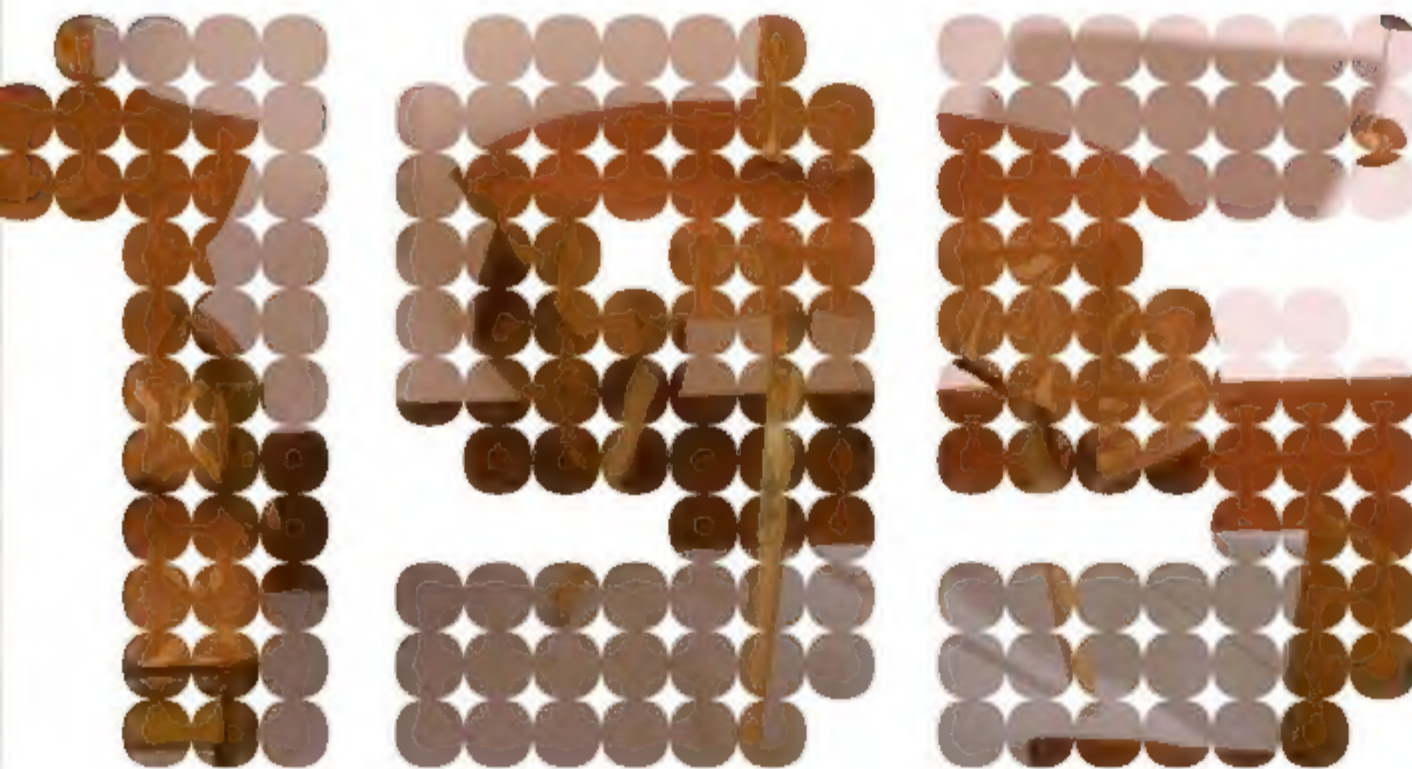








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Some people enjoy the sounds of other people eating → p59

## WHAT WE'VE FOUND OUT THIS MONTH

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Machine learning algorithms can be sexist → p38



There could be more water in Earth's mantle than in the oceans → p66



Christmas is the worst day of the year for house fires → p91



# WELCOME



Oh dear, it's Christmas again. I'll be honest, this time of year fills me with dread. For all the joy I'm supposed to giving to the world, the unrelenting jingles, marauding shoppers and saccharine TV ads leave me, well, joyless. And then, when the day itself arrives, it brings with it awkward gift-exchanges, schmaltzy movies and the only meal of the year that takes eight hours to cook and 10 minutes to eat.

It's actually in the aftermath, once the Queen goes into hibernation and someone's been murdered on *EastEnders*, that the festive season really gets going for me. With the Snowman melted for another year, I can now do Christmas properly: *Die Hard* and *Lethal Weapon* punctuated by the Christmas Lectures (p82).

The post-Christmas period also has a special place in my heart since it's the only time of year you can legitimately put roast potatoes and gravy in a sandwich. More than that, though, it's also one of the few times of the year I can – with a clear conscience – hide myself away with a good book. Disappearing into a long read feels like a luxury after a busy year. If, like me, you enjoy a good book over the Christmas period, then turn to p98 for some of the year's best science reads – and in the meantime, head to p42 to enjoy some of the best writers in the world sharing seven of the most interesting ideas in science today.

Either way, enjoy the winter break and see you in 2019!

*Daniel Bennett*

Daniel Bennett, Editor

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### MARCUS CHOWN

The laws of the Universe are not, it turns out, as immutable as we thought. Award-winning cosmology writer Marcus Chown explores this idea. → p48



### MIKA MCKINNON

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### KATHRYN MANNIX

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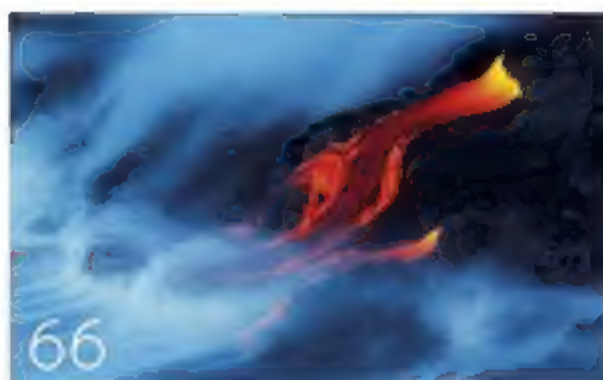
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## SPECIAL ISSUE



### THE SCIENCE OF TRUE CRIME

In this special edition from *BBC Focus*, we investigate the science that will help catch criminals, take a look at the psychology of psychopaths, and find out how crime scene investigation works (it's not like it is on telly).

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Your opinions on science, technology and *BBC Focus*

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## MESSAGE OF THE MONTH

### A less-than-helpful app

I wonder if I'm the only one to raise an eyebrow at the directions technology sometimes strays into, or ponder the uncritical manner in which such things are sometimes reported?

I read in the Out There section of *BBC Focus* (December, p100) that there is now an app called *Pplkpr*, which can tell me who I like, who I don't, and that I might be happier if I kept company with the former and avoided the latter. I'm guessing that this app might remove some of the difficulty in managing interactions with those we don't really care for, but surely learning to deal with those we don't unequivocally like is part of becoming a functioning social being?

Removing the need to acquire such a skill is potentially detrimental. I think Jeff Goldblum's character in *Jurassic Park* got it right in suggesting that people got too wrapped up in whether they 'could' do something to ask the simple question as to whether they 'should'!

Simon Bartlett, via email

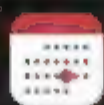
You're quite right. It's difficult to predict the social and psychological consequences of automating parts of our lives that we would otherwise consider consciously. Exhibits like *Intimacy* at the Science Gallery Dublin, where this app was showcased, present radical ideas in a forum where we're primed to consider them critically – it's probably here that such ideas belong.

– Helen Glenny, *Out There* editor

### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins an **Evoko Groupie**, a sleek and stylish alternative to the cumbersome selfie stick. The wide-angle lens easily adheres over an existing phone, computer or laptop camera. It can be used to enhance video calling or group photos, to ensure everybody is in shot. [evoko.se](http://evoko.se)

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Calendar in 5d  
Hang out with Beth again.



The *Pplkpr* app could stop us honing our social skills, says Simon Bartlett

### MSG's no good for me

I found your feature on monosodium glutamate (November, p101) to be of great interest, as I am allergic to this substance and it is dangerous to me. If I ever eat a Chinese meal, my eyes start to water and my throat closes over to a dangerous extent. I have no other allergies and this one is listed on my hospital notes.

I may be in a small minority, but this substance is not harmless. I miss my favourite takeaway, but I won't risk such a frightening experience! Bill Leahy, via email



MSG is not harmless, says Bill Leahy

### Why north?

I very much enjoyed your article on the proposed British spaceport in Scotland (November, p76). The story was missing one important element, though, in my opinion. That is, what is the logic/benefit, specifically in terms of the rotation of the Earth, of siting a space launchpad so far to the north?

You rightly mention Cape Canaveral in the USA. One reason the Americans chose that site was because it's about as far south as you can go in the USA. The benefit, of course, is that the closer you are to the equator, the faster the surface of



the Earth is travelling at that latitude, due to the law of preservation of angular motion (I think that's what it's called!).

The same principle is used as a plot device in Andy Weir's recent book *Artemis*, where Konya becomes a leader in the space industry simply because it is geographically close to the equator. Basically, harnessing the centrifugal force generated by Earth's spin as a natural boost to put a rocket into space reduces the amount of work required of the chemical reaction of the thrusters.

Anyway, I'm sure you understand the science behind it. My point is, why was this not mentioned at all in the article? It's surely a fundamental consideration in where to site a spaceport.

Rob Kaczmarek, via email

As mentioned in the article, the location in northern Scotland is a great spot for a spaceport. It is ideally placed to launch satellites into polar orbit, which is an increasingly popular practice.

– Daniel Bennett, editor

### Not that clever

I would like to take issue with your article on recreating the

Arie Elberse thinks that Neanderthals are misunderstood

Neanderthal mind (November, p42), which contains three statements that I find pretty arrogant! The offending lines are "Many academics believe our ancestors outcompeted Neanderthals by being smarter"; "finding out why *Homo sapiens* survived while *Homo neanderthalensis* died out"; and "archaeological evidence tells us that we had burial rituals, cave art and tools that surpassed anything created by the Neanderthals".

*Homo sapiens* started to move out of Africa 50-60,000 years ago. It was once thought we appeared in Europe around 35,000 years ago, and we coexisted with Neanderthals after that. The article states that the Neanderthals were successful for 250,000 years, so if we coexisted for a few thousand years, maybe they taught us a trick or two how to survive? What's more, if my maths is right, we have to survive another 215,000 years before we can really start to brag about being smarter!

In the meantime, in the 35,000 years we've been here, it is not only the Neanderthals that disappeared – more and more species are disappearing on our watch. Arie Elberse, Ireland



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EYE OPENER

## Bitey mite

SAINT PIERRE, RÉUNION

A tiny *Varroa destructor* mite clings to the hairs next to a honeybee's eye (seen here on the right).

Female mites attach to adult bees, sucking their haemolymph (insect 'blood') and spreading viruses. To make matters worse, when the bee returns to its hive, the mite crawls off into a brood cell containing a bee larva and gets itself sealed inside, where it lays its eggs. When the young mites hatch they feed on the developing bee pupa, which later emerges from its cell weakened or deformed.

"Mites can be controlled chemically and by dusting the bees with fine powders," says entomologist Prof Adam Hart. "But perhaps the best method is to breed bees that remove infected pupae from the brood cells before the mites can mature."


This picture, and those on the next five pages, were among the winning images in the recent Nikon Small World photography competition.

NIKON SMALL WORLD 2018









EYE OPENER

## A nose for mangoes

SOUTH PERTH, AUSTRALIA

Seen up close like this, the snout of a mango seed weevil (*Sternochetus mangiferae*) appears to be of elephantine proportions. But it's actually tiny – the entire creature only measures 7 to 10mm in length.

The insect, which is a major agricultural pest, gets its name from its practice of laying its eggs in mangoes. When the weevil larvae hatch about a week later, they burrow into the fruit's seed to continue developing.

WITH SMALL WORLD 2012



# EYE OPENER

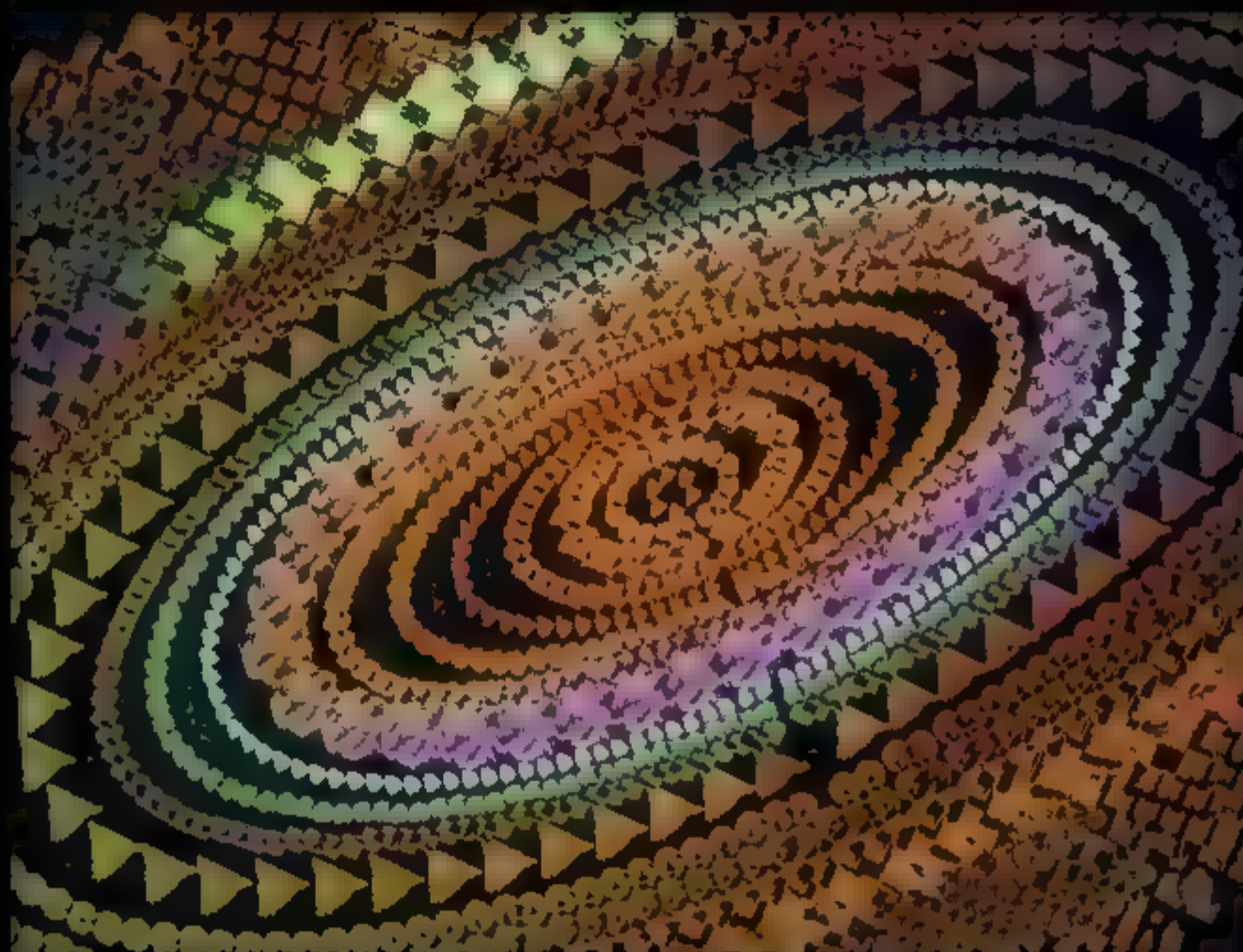
## Psychedelic security

ATHENS, GREECE

Don't worry, this isn't one of those frustrating Magic Eye pictures: it's a close-up of a security hologram such as those on your credit card or passport.

The 3D images are added to such documents to make them harder to counterfeit, as it takes advanced equipment to produce them. Faking them isn't impossible, however, which is why you're advised to update your passport and credit cards every few years to improve your chances of staying one step ahead of the forgers.

NIKON SMALL WORLD 2018



# EYE OPENER

## Dry your eyes

BALTIMORE, USA

Despite looking furry enough to use as a face flannel, this is actually a human tear.


Tears contain a wide array of different proteins, fats and minerals, and each one's particular chemical make-up hinges largely on which of the three types of tear it is: basal (to lubricate the eye), reflex (to flush out irritants) or emotional tears.

It's the crystallisation of these different chemical ingredients that gives a teardrop its unique, snowflake-like appearance, as captured in this darkfield micrograph image.

NIKON SMALL WORLD 2018







EYE OPENER

## Bling wing

RAMOS MEJIA, ARGENTINA

The Madagascan sunset moth's wings are covered with iridescent scales that appear to glimmer in the light. Unlike most moth species, this one is active during the day. Its colours warn predators that it is poisonous and not worth their trouble.

The moth's scales, seen here at 20x magnification, are essentially modified hairs. The colour comes not from pigments, but from two clever ways in which the scales manipulate light.

First, the scales are made of alternating layers of cuticle material and air. Light waves reflected off these layers interact with each other, and the number of layers in the scales varies, so different wavelengths are reflected more strongly at different points, creating these awesome colours.

Second, the curved shape of the scales causes light to be reflected from scale to scale, enhancing the overall effect.

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# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

CHR STMAS 2018

EDITED BY JASON GOODYER



AVIATION

## STAR TREK-INSPIRED AEROPLANE POWERED BY 'IONIC WIND' TAKES FLIGHT

Say hello to the world's first aircraft to fly without propellers, turbines, or any moving parts at all



"IN THE LONG-TERM FUTURE, PLANES SHOULDN'T HAVE PROPELLERS AND TURBINES. THEY SHOULD BE MORE LIKE THE SHUTTLES IN *STAR TREK*. THAT JUST HAVE A BLUE GLOW AND SILENTLY GLIDE"

A group of engineers at MIT have built the first-ever aeroplane capable of flying without any moving parts. The aircraft uses an ion drive that produces a flow of ions powerful enough to propel it forwards, in place of the more traditional propellers or turbine blades. This means it doesn't depend on fossil fuels to fly and is completely silent. The inspiration for the design came from sci-fi TV shows.

"In the long-term future, planes shouldn't have propellers and turbines. They should be more like the shuttles in *Star Trek* that just have a blue glow and silently glide," said Prof Steven Barrett, from MIT's department of aeronautics and astronautics. "This is the first-ever sustained flight of a plane with no moving parts in the propulsion system. This has potentially opened new and unexplored possibilities for aircraft which are quieter, mechanically simpler, and do not emit combustion emissions."



In the near term, ion propulsion systems could be used to fly drones, but in the long term they could be paired with more conventional combustion systems to create more fuel-efficient, hybrid passenger planes and other large aircraft, according to Barrett.

The ion drive is powered by lithium-polymer batteries and generates an 'ionic wind' – a stream of ions produced when a current is passed between a thick and thin electrode – which provides enough thrust to keep the craft airborne.

The craft has a wingspan of about five metres.





and weighs roughly three kilograms. It completed 10 flights of approximately 60 metres inside a gym at MIT's duPont Athletic Center in Cambridge, Massachusetts. The members of the team are now working on increasing the efficiency of the drive.

"It took a long time to get here," said Barrett. "Going from the basic principle to something that actually flies was a long journey of characterising the physics, then coming up with the design and making it work. Now the possibilities for this kind of propulsion system are viable."

**ABOVE** MIT's ion-drive-powered plane takes its first flight

**LEFT** Batteries in the tan section at the front of the plane supply voltage to electrodes (horizontal lines) strung across the plane. These generate the ionic wind that drives the craft

## EXPERIMENT COMMENT

### Prof Guy Gratton

*Associate Professor of Physics, MIT*  
*Principal Investigator, MIT Ion Drive Project*

"This is very clever application of the principle of ion thrusters to an aircraft, using high voltages to ionise then

accelerate the ions to produce thrust. The MIT team has demonstrated a proof of concept for this technology, which is a significant achievement.

The MIT team has demonstrated a proof of concept for this technology, which is a significant achievement. The MIT team has demonstrated a proof of concept for this technology, which is a significant achievement.

trying hard to find ways to use electric propulsion. This technology will offer something else that in the future may allow manned and unmanned aircraft to be more efficient and non-polluting. In particular, the fact that they have already got this out of the laboratory, and

into a real-world application, is a significant achievement. The MIT team has demonstrated a proof of concept for this technology, which is a significant achievement.

1960s, but developed for real by scientists and engineers in the US and at Britain's Royal Aircraft Establishment at Farnborough. They are only able to produce very low amounts of thrust, but are extremely efficient because they accelerate particles to an extremely high speed using electricity, rather than having to burn any kind

of fuel.







Earth's water is believed to have arrived here on asteroids, but that may not be the full story.

## EARTH'S WATER MAY NOT ALL HAVE COME FROM ASTEROIDS

Well, this has blown some of the current thinking out of the water! Asteroids typically get all the credit for bringing H<sub>2</sub>O to Earth, but a new study suggests they may have to share the limelight with another source – the solar nebula, the cloud of gas and dust that eventually coalesced into the Sun and the rest of our Solar System.

Scientists from Arizona State University researching the chemical composition of Earth's water have found that some of it doesn't match the profile of the ice that arrived in asteroids. By checking the ratio of hydrogen to deuterium (a hydrogen atom containing an extra neutron) in water samples, the team could determine the water's likely source.

The ratio of hydrogen to deuterium in ocean water is a good match for asteroids, but oceans do not account for all of the Earth's water. The rest of it is dissolved in rocks beneath the surface in the planet's mantle, and there's more deuterium in the mantle than can be accounted for water delivered by asteroids alone. The team thinks that as the Earth was forming, molten iron on the embryonic

planet's surface absorbed hydrogen from the solar nebula and drew it down towards the early Earth's centre. The deuterium atoms that came along with that hydrogen weren't absorbed, however: they remained in what became the mantle and were added to by subsequent asteroid impacts.

Dr Jun Wu, lead author of the study, says further clues to support this theory may be the presence of other elements buried within the mantle. "Besides the hydrogen that the embryonic planet captured we expect it also caught some carbon, nitrogen and noble gases from the early solar nebula. These should have left some isotope traces in the chemistry of the deepest rocks."

The finding fits neatly into current theories of how the Sun and planets formed, but also has implications for habitable planets beyond the Solar System. Many of these exoplanets are believed to have formed far from the zones where water-rich asteroids and other building blocks might have been encountered, but they could still have collected hydrogen gas from their stars' solar nebulae in the same way Earth did.



## ZOOLOGY

# ORANGUTANS HOOK UP TOOL-BASED SOLUTIONS QUICKER THAN HUMAN KIDS

Maybe we should want to be like them! Orangutans may be more innovative than human children, a new study at Germany's Leipzig Zoo has found. An international team of biologists and psychologists researching tool-making in orangutans have evidence that the great apes can solve a problem faster than children younger than eight. The great apes aren't just faster at coming up with the solution, though – they're also able to do it independently.

"We confronted the orangutans with a vertical tube containing a reward basket with a handle and a straight piece of wire. A second task involved a horizontal tube containing a reward at its centre and a piece of wire bent at 90°," said cognitive biologist Isabelle Laumer, who led the study. "Retrieving the reward from the vertical tube required the orangutans to bend a hook into the wire to fish the basket out. The horizontal tube in the second task required them to straighten the bent piece of wire and push the food out of the tube."

Several orangutans mastered both problems, with two doing so in a matter of minutes. The human children, however, weren't so successful. Three- to five-year-old children rarely succeed in the tasks, and less than half of seven-year-olds tested were able to figure them out. It was only the eight-year-olds that were consistently able to create the required tools.

It's not all bad news for the human race, though. Children in all tested age groups succeeded when shown how to make and use the necessary tools, which suggests they can comprehend what tools are required and how to make and use them, but that they face some sort of cognitive obstacle in innovating them.

"Complex problem solving has been associated with certain areas of the medial prefrontal cortex, which mature later in human children," said Laumer. "This, and children's strong reliance on social learning, might explain their success at a later age."

Orangutans: smarter than seven-year-old children

## IN NUMBERS

## 30.4 KM

The width of an impact crater discovered under 800m of ice in Greenland. It is thought to be the result of a 1.6km-wide iron meteorite that slammed into the planet 12,000 years ago.

## 13,000 KM

The distance flown by willow warblers during their autumn migration – the furthest ever recorded for a bird weighing less than 10 grams.

## 4,000 YEARS

The age of a vast network of termite mounds found in a tropical rainforest in northeast Brazil





## SPACE

"It may be of artificial origin,  
on a reconnaissance mission"

*In 2017, astronomers spotted the mysterious interstellar object 'Oumuamua. Now, a study by Harvard's Prof Avi Loeb suggests it's propelled by light – so could it be an alien probe?*

ABOVE Planets form in a star's protoplanetary disc, but such a mechanism is unlikely to have formed a cigar-shaped object such as 'Oumuamua

#### What is 'Oumuamua?

'Oumuamua means 'messenger from faraway' or 'a scout that arrived first', in Hawaiian. It's the first object ever discovered in the Solar System that comes from outer space. We can tell that because it's moving too fast to be bound to the Sun gravitationally.

#### What's so unusual about it?

It appears to have an extreme shape that's 5 to 10 times longer than it is wide, based on the reflected sunlight. If it's a perfect reflector, it's at least 20 metres in size; if not, then it's hundreds of metres in length. So it doesn't look like any asteroid we've ever seen.

It also deviates from the orbit that we'd expect based on the Sun's gravity and that's due to some extra force acting on it. For comets, such a force would be provided by the evaporation of ice on the surface. But there's no cometary tail around the object and, moreover, you would expect a significant fraction of its mass to be evaporated to give it the boost that's needed. Plus, it rotates every eight hours – its rotation period would have changed if it was propelled by the rocket effect from cometary evaporation.

#### How did the object reach us?

In our paper, we basically explain the extra push that it has based on sunlight pushing it – the radiation pressure.

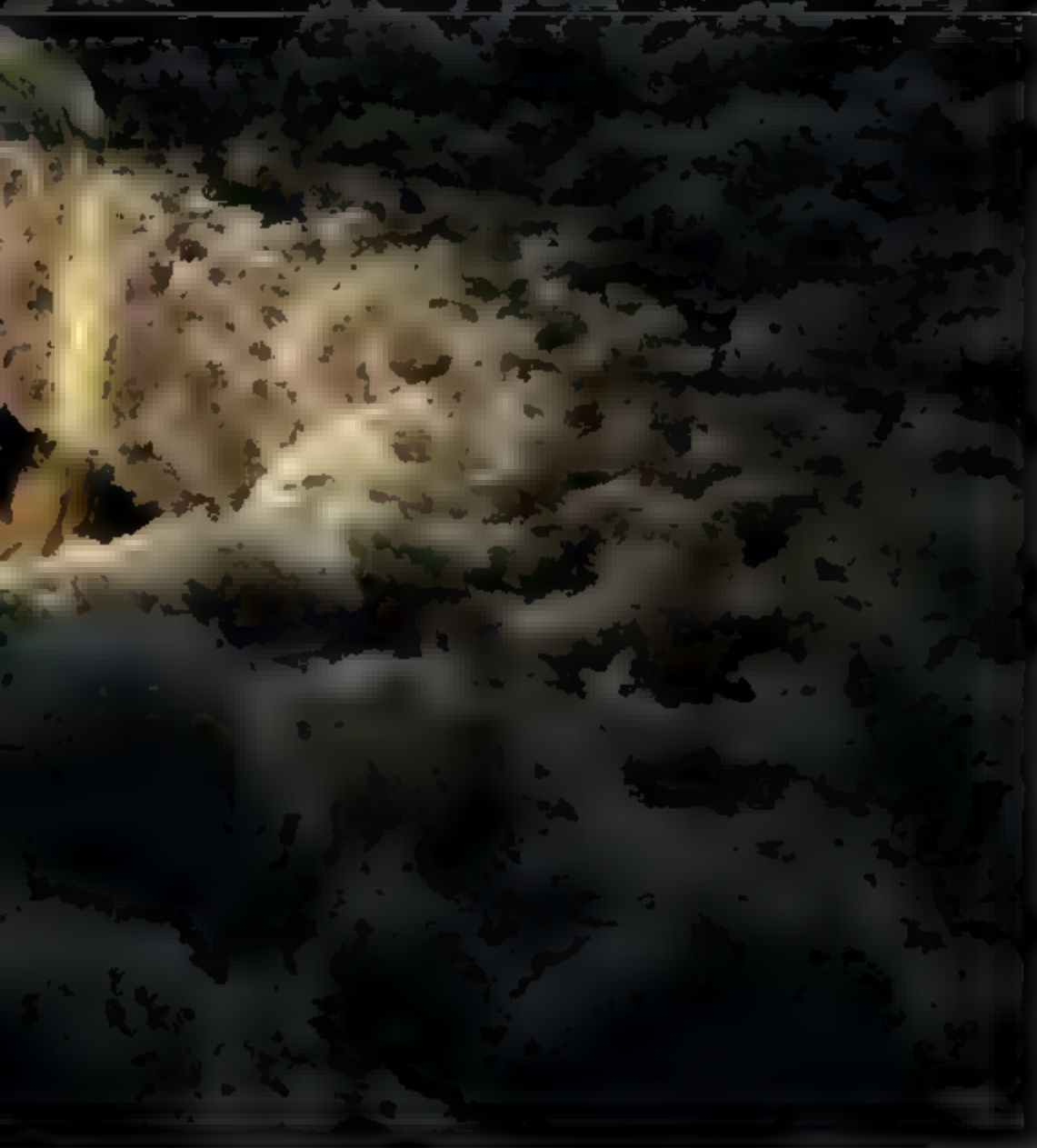
Just as a sail boat moves forward due to the reflection of air from the wind, so light exerts a force when it's reflected off a surface. So we're suggesting maybe it's a light sail, because I couldn't imagine making a thin structure just naturally in the interstellar medium or a protoplanetary disc [dust and gas that goes on to form planets]. If anyone else has a better explanation, then they should put it forward.

#### Could it really be an alien probe?

Yeah, that's one possibility, that it may be of artificial origin. It could be some defunct technological equipment, it could be on a reconnaissance mission. We [humans] are now developing light sail technology and it's possible that another civilisation out there has already mastered this technology.

People are contemplating a mission to chase down this object and take a photograph by flyby, but it moves faster than chemical rockets, so we need to develop technology that's more capable.

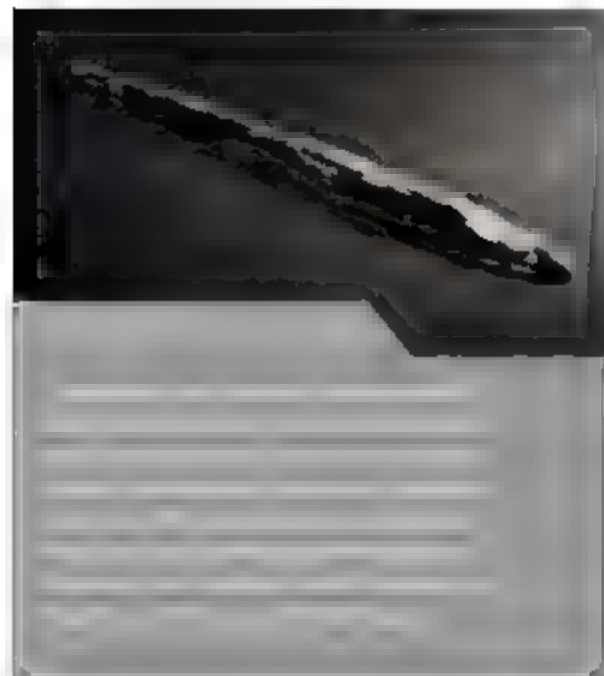




A simpler approach would be to look for other objects of the same type.

#### Will 'Oumuamua change astronomy?

I think it opens a new frontier for research. The traditional way to search for extraterrestrial intelligence is by looking for signals. This is just another way, looking for space debris, searching the sky for objects that may be artefacts of other civilisations. The mere discovery of this object is a surprise, because you need  $10^{15}$  or a thousand trillion objects ejected by every star in the Milky Way galaxy in order for us to have seen one at random. A decade ago, I predicted there shouldn't be any observed with existing surveys. Within a few years, there will be a new survey by the Large Synoptic Survey Telescope that will be much more sensitive.



## THEY DID WHAT?!



## MUSIC PLAYED TO CHEESE

#### What did they do?

Researchers at the University of the Arts in Bern, Switzerland, blasted a batch of maturing Emmentaler cheese with a mix tape that included tunes from classic rockers Led Zeppelin, hip-hop legends A Tribe Called Quest and excerpts from Mozart's opera *The Magic Flute*.

#### Why did they do that?

Some gardeners have long maintained that talking to their plants, or even playing them music, helps them to stay healthy and grow more quickly. And believe it or not, there is a small area of research known as sonochemistry in which researchers investigate the effect of exposure to ultrasound on chemical reactions. The team wanted to see if sound waves could affect the chemical processes going on within a cheese as it matures.

#### What did they find?

The results won't be in until next year, but the team are hoping that the resulting cheese will be a hit with everyone who tastes it.



## MEASUREMENT

# THE WEIGHT IS OVER: THE KILOGRAM HAS A NEW DEFINITION

*The kilogram, along with several other standard units, is being redefined by the International Bureau of Weights and Measures*

How much does a kilogram weigh? It's a simple question with a complicated answer – and next May, that answer is changing for the first time in over a century.

As it stands, a kilogram is defined by a lump of metal kept in a safe in Paris. Officially called the International Prototype of the Kilogram (IPK), but more affectionately referred to as Le Grand K, it's a cylinder made from a platinum-iridium alloy that has defined the kilogram since 1889, when it was officially sanctioned and put into storage at the International Bureau of Weights and Measures (BIPM) in France. There are also several copies of it around the world – the UK's specimen is held by the National Physical Laboratory (NPL) in Teddington.

Before the metric system was created, weights and measures varied from nation to nation, and even within countries. But after the French Revolution, the movement to create a

universal standard started gathering pace. Eventually the first physical standards were created. Le Grand K among them. Over time, scientists have replaced these standards with more robust definitions – with the kilogram the last to go.

For decades, metrologists (scientists who specialise in measures) have known that Le Grand K's weight changes due to atmospheric conditions. Being a physical object means the IPK is subject to its environment: pollution in the air can bind to the metal, adding weight, while wear caused by handling can decrease its mass. Every 40 years, the IPK and its copies are compared. Those measurements show the weight of the copies increasing by tens of micrograms, relative to the original which remains, by definition, 1kg.

In November, scientists voted to scrap the existing definition of a kilogram in favour of a new one based instead on a fundamental constant of nature known



The new kilo is defined using a Kibble balance – a high-tech electronic weighing scale





A standard half-kilogram at the US's National Institute of Standards and Technology



as the Planck constant. The new definition applies from 20 May 2019.

Scientists, and more specifically metrologists, should be pleased they now have a perfectly stable definition for the SI unit of mass," says Dr Stuart Davidson, head of mass metrology at NPL. "This will impact pharmaceutical research and production, micro-fabrication and robotics, and in the longer term it could be used in areas such as personalised medicine."

The new definition will work using a Kibble balance, which uses a current-carrying wire in a magnetic field to balance the mechanical energy exerted by an object with mass. Scientists can then calculate the weight of the object by moving the coil and measuring the speed with a laser, and using universal constants such as the speed of light and Planck's constant.

It's not just the kilogram that's getting a new definition. Our measures of temperature (Kelvin), electric current (ampere) and amount of substance (mole) are all getting new definitions, also based on fundamental constants. The other three base units defined by the International System of Units – our measures of time (second), length (metre), and luminosity (candela) – are already based on fundamental physical constants, so will not change.

**Kelly Oakes** is a freelance science journalist with a degree in physics.



LEFT: Graphene nanoribbons (black) harvest energy generated by cyanobacteria (green) 'bio ink' (green)

BELOW: Close-up image of the cyanobacterial bio ink



## ENERGY

## MUSHROOMS UNLOCK ENERGY-PRODUCING POTENTIAL OF CYANOBACTERIA

There's a new recipe for clean energy: take some cyanobacteria, add mushrooms, produce power. The correct combination of ingredients was discovered by researchers at the Stevens Institute of Technology in New Jersey, who were investigating ways to exploit cyanobacteria's ability to generate electricity.

Cyanobacteria proliferate in Earth's oceans and produce energy by photosynthesizing sunlight. But we've so far been unable to exploit their energy-producing ability because the microorganisms can't live on the artificial surfaces needed to draw an electric current.

Mushrooms, however, naturally host a variety of microorganisms. Dr. Manu Mannoor and Dr. Sudeep Joshi, two engineers at the Stevens Institute, wondered if the fungi could provide the right habitat for the cyanobacteria to survive and produce electricity.

To test this, the pair used a 3D printer to print a network of electricity-collecting graphene

"WE SHOWED THAT A HYBRID SYSTEM CAN INCORPORATE AN ARTIFICIAL COLLABORATION BETWEEN TWO DIFFERENT MICRO-BIOLOGICAL KINGDOMS"

nanoribbons onto a white button mushroom. Then they printed a spiral of 'bio ink' laced with cyanobacteria around the mushroom's cap. Shining a light on the mushrooms activated the cyanobacterial photosynthesis, generating a photocurrent and allowing electrons to transfer through the membranes of the cyanobacteria to the conductive network of graphene nanoribbons on the mushroom's surface.

"The mushrooms essentially serve as a suitable environmental substrate [that has an additional function] of nourishing the energy-producing cyanobacteria," says Joshi. "We showed, for the first time, that a hybrid system can incorporate an artificial collaboration, or engineered symbiosis, between two different microbiological kingdoms."

At this point, the amount of electricity the process produces is tiny, but Mannoor and Joshi have demonstrated that it can be boosted by packing the mushrooms together densely.



## SPACE

## BLACK HOLE MERGERS SPOTTED FOR THE FIRST TIME

The picture below shows the moment two become one: astronomers have caught the first images of black holes combining to form the cores of new galaxies.

A team led by Eureka Scientific's Dr Michael Koss used the WM Keck Observatory in Hawaii, the Hubble Space Telescope, and the Burst Alert Telescope (BAT) aboard NASA's Neil Gehrels Swift Observatory, to find and photograph several pairs of merging black holes.

Coalescing galaxies have been spotted before, but only in their early stages. The final stage of the process, in which their respective black holes merge, has never been imaged before because it occurs behind the enormous, dense cloud of gas and dust that is produced as each of them consumes the surrounding material.

The team was able to overcome this obstacle with the help of X-ray data gathered by the BAT. "Gas falling onto the black holes emits X-rays [that penetrate the surrounding cloud] and the brightness of the X-rays tells you how quickly the black hole is growing," Koss explained.

The BAT data pointed to the locations of possible black hole mergers and was cross-referenced against an

archive of Hubble images of coalescing galaxies. Koss's team then turned to the infrared telescopes at the WM Keck Observatory that could peer through the dust cloud to spot the black holes coming together.

It's long been hypothesised that coalescing galaxies play a key role in the formation of supermassive black holes, which lie at the core of galaxies like our own Milky Way. But, until now, there has been no observational evidence to support the idea.

"Computer simulations of galaxy smash-ups show us that black holes grow fastest during the final stages of mergers, near the time when the black holes interact, and that's what we have found in our survey," said study team member Laura Blecha of the University of Florida, in Gainesville. "The fact that black holes grow faster as mergers progress tells us galaxy encounters are really important for our understanding of how these objects got to be so monstrously big."

The images presage what could happen in a few billion years, when our Milky Way merges with the Andromeda Galaxy. Both galaxies host supermassive black holes at their cores, which will eventually smash together into one larger black hole.



## BRITISH WINE LOVERS

Maybe the only way is Essex... at least when it comes to wine. A study at the University of East Anglia has found that changing weather in southern England is creating conditions similar to those found in Champagne, France.

## SHOP OWNERS

A University of Arizona study has found that most customers, including those who prefer to shop online, do not want physical shops to close down. Shoppers see bricks-and-mortar stores as part of the social fabric of our society, they say.

## GOOD MONTH

## BAD MONTH

## UNTIDY TEENS

Take heed, teens. A study carried out at the University of Rochester, New York, has found that quiet, tidy teens are more likely to live into their sixties. The effect could be due to tidy people being more likely to adopt healthy lifestyles, they say.

## CEPHALOPODS

Traditional fish, such as cod, are in short supply. But a team at the University of Copenhagen has found a solution for seafood lovers: eat more squid and octopus. This is because their populations look set to increase, due to climate change.





ARCHAEOLOGY

## 310-MILLION-YEAR-OLD FOOTPRINTS LEFT BY 'LINE-DANCING' REPTILE-LIKE CREATURE DISCOVERED IN THE GRAND CANYON

Cotton Eye Joe hasn't got anything on this guy: a set of footprints left by a sidestepping reptile-like creature have been discovered covering a fallen boulder along the Bright Angel Trail in the Grand Canyon, Arizona.

The tracks were first discovered in 2016 by a group of hikers, who then alerted Prof Stephen Rowland, a geologist at the University of Nevada. The tracks are estimated to be around 310 million years old and date back to a time when the supercontinent Pangaea was being formed, making them the oldest ever found in the Grand Canyon.

"My first impression was that it looked very bizarre because of the sideways motion," said Rowland. "It appeared that two animals were walking side by side. But you wouldn't expect two lizard-like animals to be walking side by side. It didn't

make any sense." After studying the tracks further and making a set of detailed drawings, Rowland came to the conclusion that the animal was moving with a 'peculiar, line-dancing gait'. "One reason I've proposed is that the animal was walking in a very strong wind, and the wind was blowing it sideways," he said.

At time of writing, it is not yet known what species the footprints belonged to – and the animal in question could well be one that has never been discovered before. "It absolutely could be that whoever was the trackmaker, his or her bones have never been recorded," said Rowland.

Rowland is now arguing for the Bright Angel boulder to be placed in the geology museum at the Grand Canyon National Park, for both scientific and interpretative purposes.



# TRENDING

Your guide to the hottest topics in the world right now

## #SLEEP

### BROKEN NIGHTS, BAD HABITS

A lack of sleep may lead to children developing poor dietary habits and spending more time using computers and smart devices. researchers at the American Academy of Sleep Medicine have found. The survey of nearly 180,000 schoolchildren found that those sleeping for less than eight hours are more likely to skip breakfast, eat fast food and sweets and stay glued to their phones all day.



### SIESTA FOR SUCCESS

Napping could boost teenagers' performance in school, a study at the University of Delaware has found. Getting 30 to 60 minutes' worth of shut-eye between 12 noon and 2pm – the so-called 'circadian dip' during which our energy levels are at their lowest – may help to boost neurocognitive function.

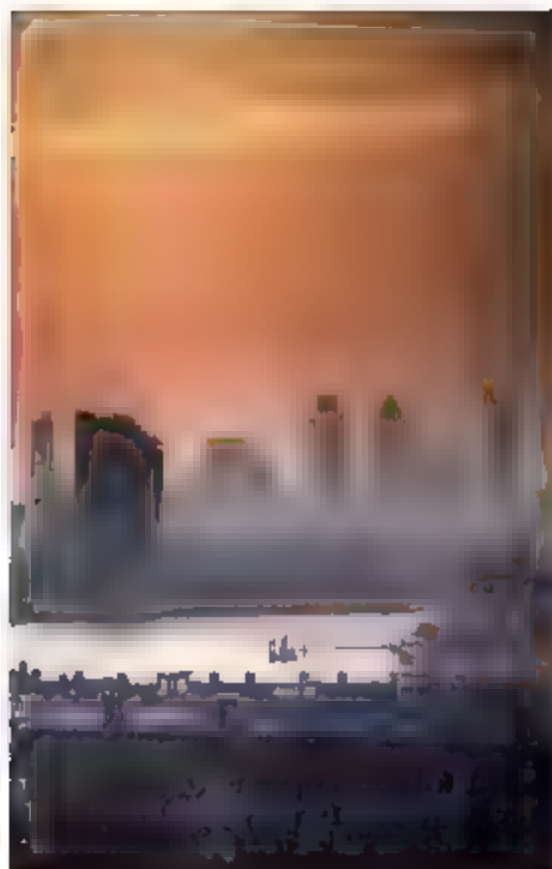
## #AIR POLLUTION

### POLLUTION CUTS LIFE EXPECTANCY

Poor air quality cuts an average of 1.8 years off the average lifespan worldwide, an analysis at the University of Chicago has found. By way of comparison, smoking reduces the average global life expectancy by 1.6 years, poor sanitation by seven months.

### IT'S GRIM UP NORTH

Clouds in the Arctic are two to eight times more likely to be seeded by air pollution than clouds at other latitudes, researchers at the Karlsruhe Institute of Technology have found. The effect could lead to the formation of clouds that act as a blanket, potentially leading to further Arctic warming, they say.



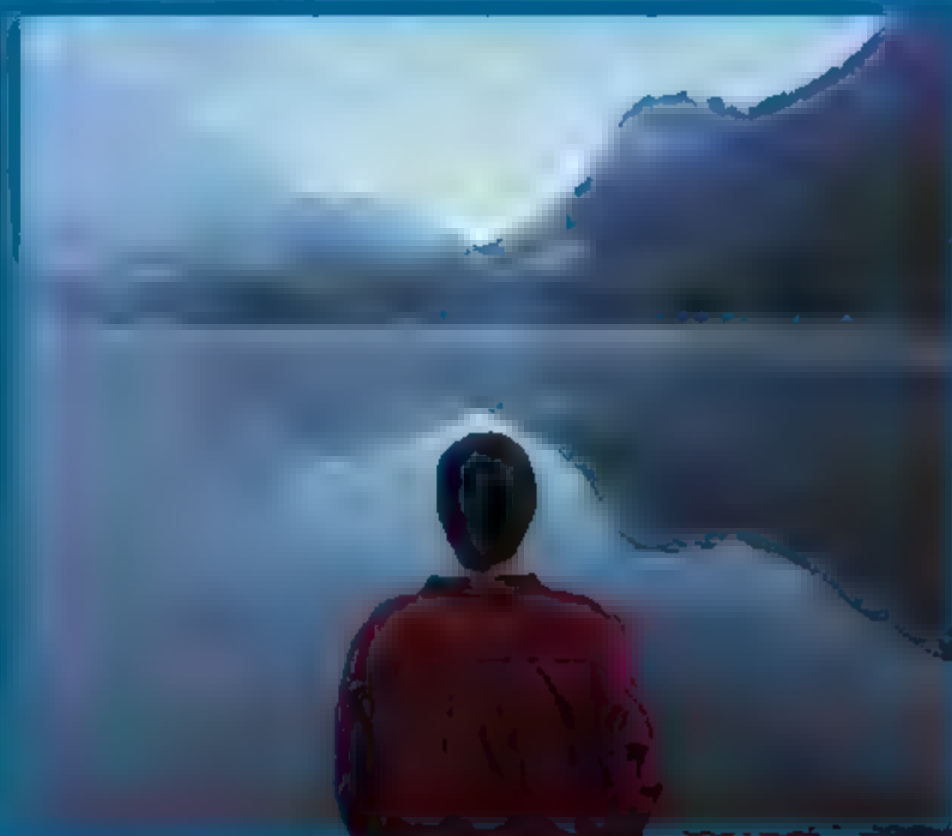
## #DEPRESSION

### CAN HORMONES HELP?

Testosterone therapy could help to treat depression in men, researchers at TU Delft, the Netherlands, have found. Their analysis, involving almost 2,000 men, suggests that hormone therapy is as effective as antidepressants in treating the symptoms of depression.

### DEPRESSION IN THE BRAIN

A team at the University of Cambridge has identified a common pattern of brain activity present in those with anxiety and depression. The researchers found that people with both conditions showed a similar pattern of activity in the brain, particularly in the hippocampus and amygdala, which was strongly linked to feelings of mood and depression. Identifying the exact nature of the pattern may help to develop more effective treatments, they say.



# Kew

## Adopt a seed now

Help protect the future of the world's plants by adopting a seed today from £25. Give a unique and lasting gift which also helps fund one of the world's most important conservation projects.

For inspiration see the full range of seeds available and find out how your gift will help our vital science work at [adoptaseed.kew.org](http://adoptaseed.kew.org)

The Royal Botanic Gardens, Kew is a charity exempt by law (under provisions of the Charities Act)

Image: Round-leaved sundew (*Drosera rotundifolia*)



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**FUNDRAISING  
REGULATOR**



# WELCOME TO THE FUTURE...



Aleks Krotoski is also a psychologist, broadcaster and comedian. She presents BBC Radio 4's *Digital Human*.

**M**any of you will have received home robots for the holidays. Congratulations on your new arrivals. You are now officially living in The Future. I live there too. Welcome to the neighbourhood. But there are a few things that you should know before you settle in, so you're not surprised later on in The Future when terrible things happen. I like to think of 1980s science fiction movies like *The Terminator*, *RoboCop* and *Total Recall* as travel guides to our modern world. In other words, how we treat that friendly Alexa, Cortana or Google Home will ultimately affect who will be lined up at the wall during the robot uprising.

At a technical level, voice-activated personal assistants are pretty incredible and take a lot of science. They require processors, wake-up words, databases, and the ability to correctly interpret a word despite age, gender, socioeconomic status, ethnic background or country of origin. So yeah, just shouting, "Hey Alexa, tell me a joke," seems a bit flippant now, doesn't it?

My point is that the way we speak to our machines has an impact on how they behave. But Amazon has just implemented a new whispering mode that will meet the human's voice volume. Why shouldn't the device eventually copy our tone too? You know, shouting at it. Ordering it around. Being polite. The robots are learning. We aren't.

Albert Bandura introduced the social cognitive theory in 1977, to explain how people learn. The idea behind it is that we behave based on what we see others doing – parents, colleagues, media, whoever. These targets of our attentions become the templates by which we live. Robots are not yet observing and assimilating; there's too much processing overhead for that. But there are often other people in our domestic lives, like friends and family, who are watching to see how we interact with

these machines. And if we're angry or rude or polite, that becomes the normal behaviour towards devices. And that evolves into how we treat robots in general and how we will feel is the right way to behave towards artificial intelligences in the future. I won't even get into the nuances of gender politics, but they're there too; most domestic personal assistants have female voices because, as was recently broadcast on BBC Radio 4's *Digital Human*, research indicated early on that people preferred to order female voices around than male ones. There's a reason we called that episode *Subservience*.

We should consider how we are speaking to our machines, or we're going to have to update *Mrs Beeton's Book Of Household Management* for the 21st Century. Victorian guides to household management kept upstairs separate from downstairs. "Not in front of the maid, darling," is the same as, "Don't say anything sensitive in front of Google Home." There are people who think that their online Google search results and the ads on their web browsers are affected by what they've said to their domestic devices. It's not currently the case, but it literally is only a matter of time.

As a new recruit to The Future, you can change things. You can be mindful of how you interact with your tabletop servant. You can recognise your conscious and unconscious biases, and how they're communicated to other people when you talk to the machine. We are the pioneers in this brave new world, and it is down to us to make The Future one in which we want to live. **Q**

**"THE WAY  
WE SPEAK TO  
OUR MACHINES  
IMPACTS HOW  
THEY BEHAVE"**



# THE POWER OF THE PLACEBO



TWO

Michael Mosley is a science writer and broadcaster, who presents *Trust Me I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* £8.99 short books

**N**ormally, I don't set out to mislead members of the public, particularly on behalf of the BBC. But I recently did so for *Horizon*, in order to explore an extraordinary phenomenon: the placebo effect. For this episode, we invited more than 100 people from Blackpool with chronic back pain to come to a medical centre and take part in an experiment. They were told they would either get a placebo, which was a pill containing ground rice, or they might get a novel painkiller. Or they might be offered nothing more than standard care (a control group). What we didn't tell them is that all those receiving pills would be getting placebos.

When our volunteers arrived, they all got a physical examination and were asked to fill out a disability questionnaire, before seeing one of four GPs. Some of them received the standard GP consultation of nine minutes and 22 seconds, while others got nearly 20 minutes.

The study was designed by Dr Jeremy Howick, an expert on the placebo effect from the University of Oxford. He was keen to see the impact of the placebo on back pain, and also wanted to measure the effect of a longer GP consultation. There is a widespread belief that only the weak-willed or gullible succumb to the placebo effect, but Howick says this is not true. The main characteristic of people who respond to placebos is that they are open to new experiences. He also pointed out that just because a placebo contains no active chemicals, it doesn't mean the effect is not real. Among other things, taking a placebo can trigger the release of endorphins – natural painkillers that are similar in structure to opioids like morphine.

Then there's placebo surgery. A few years ago, surgeon Prof Andy Carr decided to examine the effectiveness of acromioplasty, an operation that involves removing a spur of bone from the shoulder to relieve pain and improve mobility. About 25,000 are performed every year in England and Wales. Carr wondered if it was the operation



that was helping his patients, or the placebo effect. He did a trial in which volunteers were randomly selected to receive either real surgery; 'fake surgery' in which they were anaesthetised, cut open and sewn back up again; or physiotherapy. The patients who had an operation did better than those who had physiotherapy, but it made no difference whether it was a real operation or not. The NHS has since announced that it will no longer be offering acromioplasties. Patients will receive physio instead.

Back in Blackpool, after three weeks of swallowing pills, my volunteers went through another series of tests and questionnaires. Then it was time to reveal all. We discovered that nearly half of them had got significant pain relief from taking the pills, even though they were fake. The ones who did best were the ones who believed they were getting 'real' pills. And those getting the extra GP time had done almost twice as well as those who got the standard amount, which shows what a powerful effect a doctor's time and attention can have. Only 20 per cent of the control group, by contrast, saw benefits. Perhaps the most surprising thing is that when I asked them if they would like to go on taking the pills for another few weeks, knowing they were placebos, most said yes.

So where does that leave modern medicine? A recent article in the *British Medical Journal* suggested that it can be ethical to prescribe placebos, as long as the doctor tells the patient that's what they are doing. The article cites evidence that placebos can work even when the patients know that is what they are taking. **G**

**"PLACEBOS, EVEN THOUGH THEY'RE FAKE, OFFER REAL PAIN RELIEF"**



ALL I WANT FOR CHRISTMAS

These are the  
best earphones  
ever!

Tony Visconti  
Grammy award-winning  
producer: David Bowie,  
T-Rex, Iggy Pop

"They're easily the  
best in-ear earphones  
I've ever used."

Pete Paphides

DJ & Music Journalist: Melody  
Maker, The Guardian,  
& Magazine

(On the Flares® JETs)

"Nothing I have  
used comes close."

Fran Healy,  
Travis and BNQT  
(On the Flares® PRO)

### On The Flares® PRO

"Best Bluetooth Wireless Earphone 2018."  
Highly Commended T3

"Your ears are treated to what feels like such a true  
representation of the music, that songs you've heard hundreds  
of times suddenly feel very exciting again."

Mi Pro

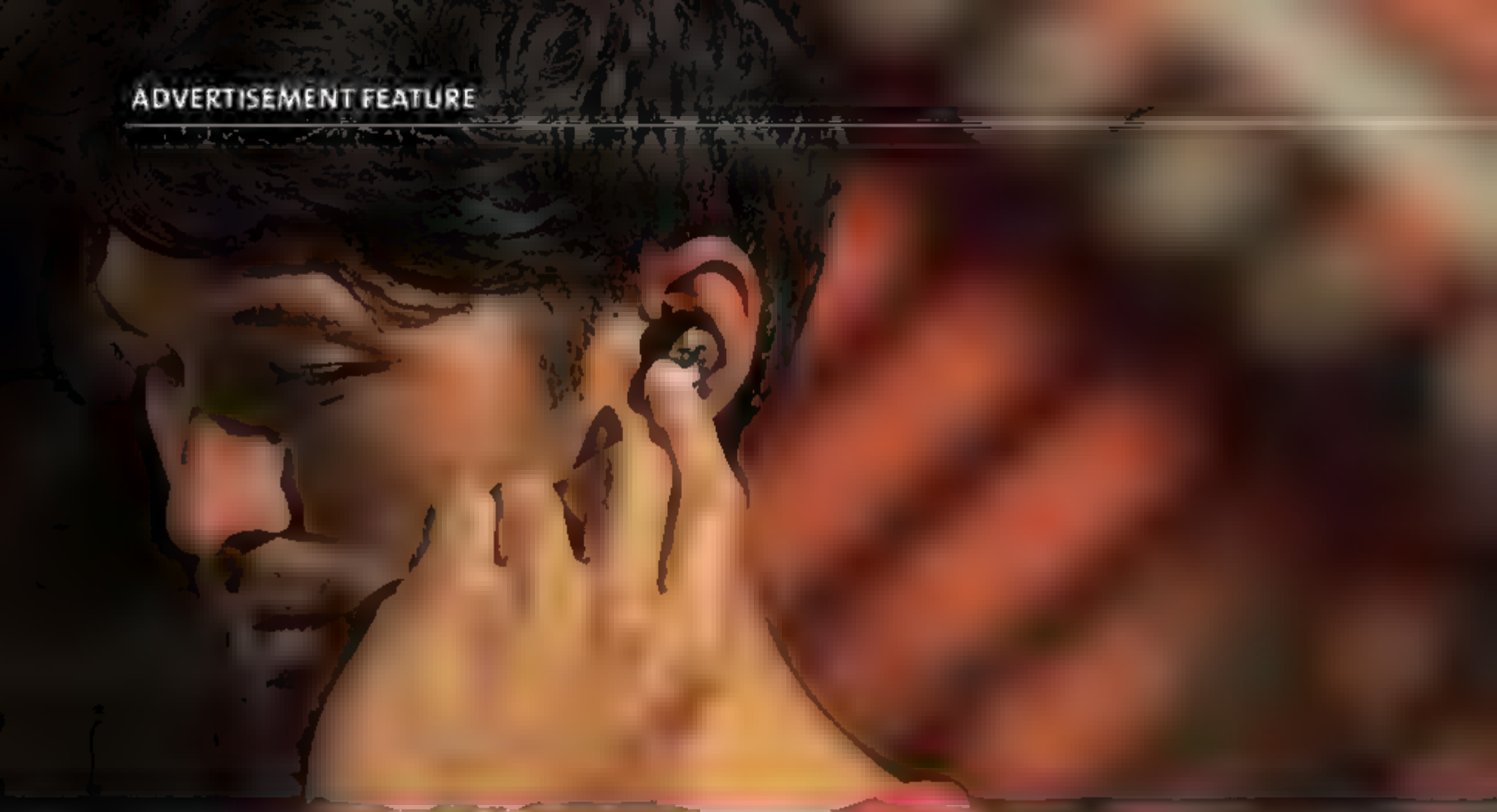
"Without a doubt they're the best  
earphones I've had the pleasure to use."  
Gizmodo

"FLARES PRO Top Spot."  
Headfonia

**FLARE**  
LONG LIVE EARS.

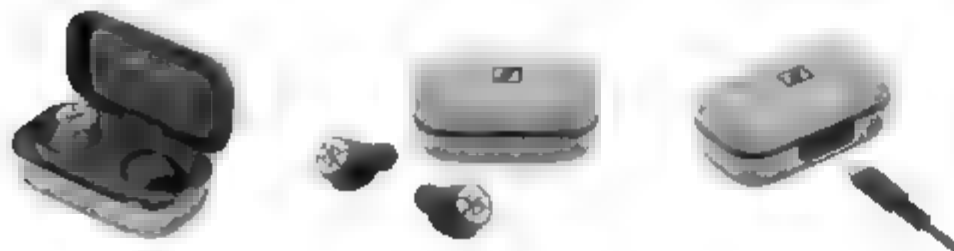
[www.flareaudio.com](http://www.flareaudio.com)





# THE WAIT IS OVER

Sennheiser's first truly wireless earbuds are here, just in time for Christmas



**T**he best things in life are worth waiting for, right? That's why when it came to releasing world-class wireless earbuds, Sennheiser took the time to make sure they were just that. The result: MOMENTUM True Wireless earbuds.

So what's so great about them? For a start, Bluetooth connection to your chosen audio device is seamless, linking up with the latest Bluetooth codec technology. What's more, you'll be able to hear every single word of every phonecall thanks to MOMENTUM True Wireless's high-quality voice pickup.

Then there's the very modern phenomenon of having to choose between having your listening experience dulled by daily life's background noise, or having the volume jacked up so high that you don't hear the crucial announcement telling you your train's been diverted. With MOMENTUM's Transparent Hearing feature, you can hear your surroundings and easily have conversations without removing earbuds.

The latest low-latency technology also provides lip-synced audio for all your media, exceeding the standard Bluetooth performance. With a four-hour battery life that can be extended to more than 12 by portable charging via the compact case, you'll be tooled up for the ultimate on-the-go listening experience with Sennheiser's MOMENTUM True Wireless earbuds.

Available at all major retailers and [Sennheiser.com](https://www.sennheiser.com)



**SENNHEISER**



# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

CHRISTMAS 2018

EDITED BY HELEN GLENNY



## 2019? BRING IT ON

Five of our favourite innovations from 2018 that show us the direction tech is heading in the coming years

Though it's been a key area of R&D interest for years, smart clothing found its way into the mainstream market in 2018. You can now get Alexa-enabled heated jackets that will warm you up on voice command, vests that do all the work of a high-tech fitness watch, or yoga pants with haptic feedback.

One of our favourites this year was the Kjus ski jacket. It uses Bluetooth-enabled technology to pump out sweat by applying electrical pulses. It promises to keep your base layers dry and prevent post-activity chills, even on energetic ski treks.

Kjus 7SPHERE HYDRO-BOT ski jacket  
£1,299, [kjus.com](http://kjus.com)

# WANTED



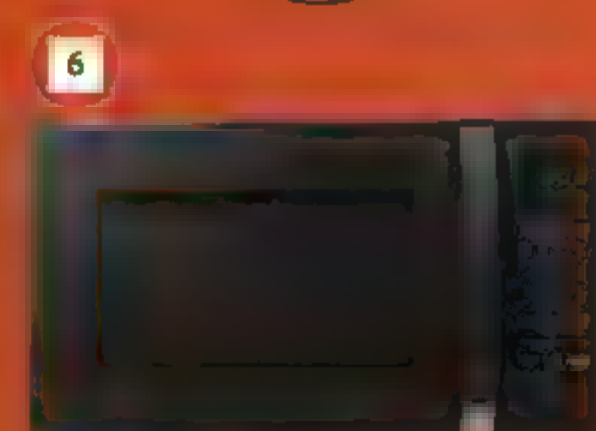
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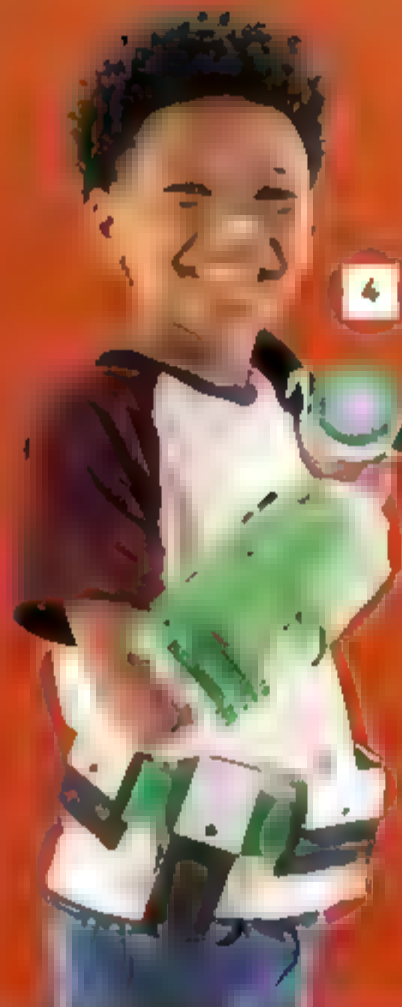
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6



3



4

1

## ROBO-BUDDIE

Research shows that 41 per cent of kids feel we're talking to a friend when speaking to Siri et al, so Anki made its new digital assistant a cute little robot who responds to voice commands and does a happy shimmy when he gets things right.

**RoboBuddie**

**\$199.99, anki.com**

2

## VR FOR THE MASSES

Oculus Go rings in a new era for VR, where you don't need to tether to a PC or slip your smartphone into a headset. It's a fully contained VR system, so just slip on the headset and go. Plus, it's at a cost that makes it more realistic for the masses.

**Oculus Go**

**\$399, oculus.com**

3

## TECH DEN

Smartphones and tablets can help kids learn and develop new skills, but overuse can cause problems. Tech Den is a device dock that lets families create rules around their use, and rewards kids for putting devices away at agreed times.

**Tech Den**

**\$199 (\$299 special), techden.com**

4

## LEGOING FOR KIDS

Loads of children are getting into coding, and the tools that help them with their new hobby are becoming ever more creative. This fabulous kit includes wearable tech sensors, in-app coding and customisable LED designs.

**LEGO Mindstorms**

**\$199.99, thebrickcompany.com**

5

## HEMIBYBABEDISH

Google recently rolled out Translate on all Google Assistant-optimised headphones, meaning that two people can have a real-time conversation, each speaking in a different language. It's not perfect, but it's a huge step forward.

**Google Pixel Buds**

**\$159, store.google.com**

6

## ALEXA EVERYWHERE

Amazon made this voice-controlled microwave to show how easily companies can make their gadgets smart. There's nothing too fancy going on, but it will automatically order more popcorn from Amazon when you're running low.

**Amazon Echo Microwave**

**\$199.99 (\$299 special), amazon.com**





### 7 BARGAIN BLOWER

OnePlus has made its name with affordable, feature-packed phones that rival those of Samsung and Apple. The OnePlus 6T follows current trends with a bigger screen, an in-display fingerprint sensor and no headphone jack.

**OnePlus 6T**  
From £499, [oneplus.com](http://oneplus.com)

### 8 IN FLIGHT

Currently our favourite drone, the DJI Mavic Air is small, light and foldable, with AI obstacle avoidance and the ability to shoot 4K video at 30fps. Though it lacks the battery life of the Pro versions, the lower price tag is well worth it.

**DJI Mavic Air**  
From £549, [dji.com](http://dji.com)

### 9 NO MORE WIRES

This year's new Apple phones finally include wireless charging, bringing the technology firmly into mainstream use. So mainstream, in fact, that IKEA is now selling wireless chargers that you can build into your furniture.

**IKEA SALLIEN wireless charger**  
From £29, [ikea.com](http://ikea.com)

### 10 E-COMMUTE

E-bikes are a fast, environmentally friendly way to commute, and a great form of exercise. Van Moof's Electric range is one of the best, with rider recognition and built-in theft defences, so you don't need to bother with locks.

**Van Moof Electrified S**  
From £2,299, [vanmoof.com](http://vanmoof.com)

### 11 GOING HANDS-FREE

With female-led tech start-ups becoming more common, women's issues are being solved with innovative gadgetry. The Elvie breast pump fits inside a bra and makes the process of expressing milk silent and hands-free.

**Elvie Pump**  
From £129, [elvie.co.uk](http://elvie.co.uk)

### 12 8K HAS ARRIVED

With Hollywood studios using 8K cameras and the Tokyo Olympics set to follow suit, we're excited to see the first 8K TV come on sale in the UK. The Samsung Q900R has AI upscaling, so it'll make your 4K or HD programmes look great.

**Samsung QLED 8K Q900R**  
From £4,299, [samsung.com](http://samsung.com)

# GAME-CHANGING TECH

Tech news in 2018 was dominated by a few key technologies with limitless applications...



These Guardian devices use Google's machine learning tools to listen for sounds of logging in the rainforest

COMPUTING

## THE BROADENING REACH OF MACHINE LEARNING

Machine learning is the process of feeding data into a program so that it 'learns' how to perform a certain task, without engineers having to explicitly program an algorithm. A few years ago, companies like Google and Microsoft open-sourced their machine learning platforms, allowing anyone to apply machine learning tools to their own projects. This year, we've really started to see the fruits of those accessible platforms, with machine learning applied to a wider range of tasks than ever before.

Machine learning is now being used, for instance, to detect the sounds of illegal

logging in the rainforest, monitor the health of dairy cows, and detect cancer cells that are too small for pathologists to see.

However, machine learning isn't without its share of controversies. It recently emerged that Amazon had to scrap an algorithm it was using to sort job applications, because it became biased towards male candidates. The algorithm was trained using employment data from the past 10 years at Amazon, and thus reflected male dominance in the tech industry. Machine learning is a powerful tool, but it's only as good as the data on which it's trained.

### MACHINE LEARNING PREDICTS EARTHQUAKE AFTERSHOCKS

In August this year, scientists from Google used machine learning to predict the location of earthquakes. The machine learning model was trained on data from the past 10 years, and it was able to predict the location of earthquakes with a high degree of accuracy. This is a significant breakthrough, as it allows scientists to better understand the patterns in the data. The machine learning model was trained on data from the past 10 years, and it was able to predict the location of earthquakes with a high degree of accuracy. This is a significant breakthrough, as it allows scientists to better understand the patterns in the data.



## MEDICINE

## AFFORDABLE PROSTHESES

We've been able to create myoelectric prosthetic limbs, where the user controls the limb's movements using their own muscles, for decades. For a prosthetic hand, it's usually using the muscles in the arm. But it's only recently that such technology became cost-effective enough to be a realistic option for most amputees. Largely, that's thanks to the rise of 3D printing, which allows engineers to produce custom parts quickly and affordably.

UK company OpenBionics creates 3D-printed myoelectric prostheses, and all of its work is open source, allowing other researchers to build on it. Georgia Institute of Technology researchers have integrated ultrasound control into one of the OpenBionics' arms, which has proved sensitive enough to allow a musician who lost his hand and forearm to play the piano again. Meanwhile, at Newcastle University, researchers have developed a bionic hand with a camera that can photograph objects and trigger movements, allowing the user to grip the objects more effectively.

OpenBionics' 3D-printed arm



### ELECTRONIC SKIN BRINGS TOUCH FEEDBACK TO PROSTHESES

Researchers at Johns Hopkins University have created an electronic skin that generates a sense of touch through a prosthetic's fingertips. The skin is made of fabric and rubber and converts touch and pain information by electrically stimulating peripheral nerves in the user's arm. The researchers are continuing to develop the technology to provide more meaningful sensory feedback.

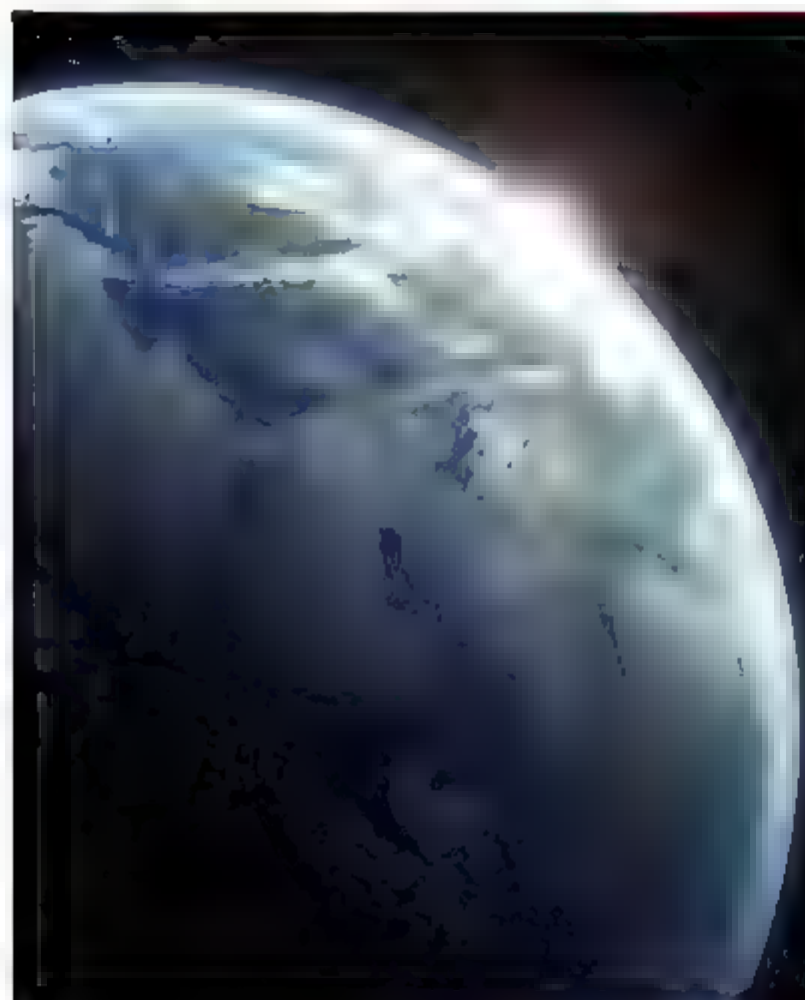
## SATELLITES

## SURVEILLANCE TO SAVE THE PLANET

If you're living in London, it's likely you'll be caught on CCTV cameras around 300 times today. Further afield, over 1,700 satellites are monitoring cities from space.

Fearing invasions of our privacy, we've traditionally distrusted mass surveillance. Yet this network of cameras can also be used to help save vulnerable species and landscapes from eradication and destruction. More than 400 infrared camera traps are monitoring the movement of giant pandas in China, while astronomers and ecologists are combining their surveillance skills to search for orangutans, spider monkeys and river dolphins.

Earlier this year, Bill Gates announced his support for a project called EarthNow. It will involve launching a network of satellites with huge amounts of processing power, capable of streaming continuous real-time images of the Earth. EarthNow's founder and CEO Russell Hannigan suggests it could be used to track whale migrations, catch illegal fishermen and detect wildfires in their earliest stages.



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# THE FUTURE IS HERE

Acclaimed bicycle manufacturer  
Specialized's new, groundbreaking  
e-mountain bike will appeal to all cyclists,  
whatever your fitness, experience or  
reason to ride...



**SPECIALIZED**



W

hat in your opinion is the greatest engineering breakthrough of recent times? Start up of the Large Hadron Collider? Elon Musk's self-landing rockets? 3D printing? Of course, there's no simple answer. You see, technical evolution is subjective; how much does progress in that field resonate with you? By how much will it improve your life? If that field involves travelling faster and further, while protecting the planet and liberally sprinkling fun, Specialized's new Turbo Levo electric mountain bike will ring loud and clear.

Nineteen of the world's leading engineers united at Specialized's Turbo Innovation Centre in Switzerland to research, design and forge the most technologically advanced bicycle in the world. That 19 included a trio

of innovators who've redefined what it means to cycle, namely team lead Vincent Patureau, electronics specialist Marco Sondegger and Joe Buckley (master of suspension). Despite the incredible success of the original Turbo Levo, Patureau, Sondegger and Buckley felt both Specialized and the bike industry could do better. That's why it has taken three years to create an electric bike that has set new standards in range, assistance and ride quality.

### GAME-CHANGER #1 THE MOTOR

Specialized tapped into over 100 years of engineering know-how by collaborating with German company Brose to produce a beautifully integrated motor and battery that extends range by a game-changing 40% over the previous model. This technical partnership has seen power output rise to 560 watts, that increase deriving from the clever application of larger magnets, which has also helped to overcome a recurring e-bike problem: overheating. It's so powerful that there's a 'walk-assist' mode where the bike will essentially climb itself to the top of a hill. While power has grown, weight has shrunk. The new Levo is 800g lighter than its elder sibling thanks to a 15% smaller motor and battery, cradled in a lightweight magnesium housing.

### GAME-CHANGER #2 THE SOFTWARE

How much assistance you receive is controlled the Turbo Connect Unit and Mission Control – the smart new app that's available to download on Android and iOS operating systems. At your fingertips sits a cutting-edge piece of software whose intuitive appeal is down to its design and creation by electronics craftsman/cyclist Marco Sondegger. Sondegger knows what a rider needs from an electric mountain bike, whether it's hitting the Brecon Beacons and covering double the distance (double the views, double the trails... double the fun) on a traditional mountain bike, or enjoying a short, mixed-terrain commute to your urban office. To that end, you can

set your level of assistance, from a gentle 35% support in Eco mode to 100% support in Turbo. The app's Smart Control can also select power assist for you. Simply set the goal and let the algorithm feed you just enough energy to reach your destination.

### GAME-CHANGER #3 THE FRAME AND GEOMETRY

Of course, technology doesn't guarantee a smooth, comfortable ride; in fact, many e-bikes are known for sending every bump and vibration chattering through to you, the pained and strained rider. Not with the Levo. The skeleton of the Levo S-Works comprises Specialized's pioneering FACT (Functional Advanced Composite Technology) carbon fibre. The strong, lightweight carbon fibre makes it the material of choice for high-performance bikes, but not all carbon is created equally. Specialized's FACT carbon fibre took cycling's greatest minds years to create, but they've hit the comfort/strength sweet spot thanks to intelligent use of: selection of fibres, ratio of fibre to resin (essentially a glue that binds carbon to add structural strength) and direction of weave. Geometry that draws on the genre-defining Specialized Stumpjumper means it handles with the tactility of no e-bike before it, while 150mm travel upfront and outback ensures road buzz and off-road noise is silenced for total comfort.

### GAME-CHANGER SUMMARY TURBO – IT'S YOU, ONLY FASTER


Mountain biking has led the tech revolution in the bike industry, from the first model in the 70s when counter-culture Californians carved up local trails to the first full-suspension frame in the early 90s. Specialized has been at the heart of this (knobbly) two-wheeled revolution with the Stumpjumper, aka the world's first major production mountain bike – celebrating its 35th anniversary this year. With the new Turbo Levo, Specialized has created the most advanced, integrated bicycle in the world. The result? You can ride further, faster and fuelled by more fun than you ever thought possible.



DISCOVER MORE ABOUT THE INNOVATIVE, INTELLIGENT NEW TURBO LEVO  
BY VISITING [SPECIALIZED.COM/NEW-TURBO-LEVO](https://www.specialized.com/new-turbo-levo)







# 7 RADICAL IDEAS TO EXPAND YOUR MIND

ILLUSTRATIONS: SCOTT BALMER

After an overindulgent festive season of trashy television and second helpings of trifle, your brain may have turned to mush. Give it something substantial to get its teeth into with these incredible ideas at the forefront of science

## 1

DYING ISN'T AS BAD  
AS YOU THINK

WORDS: DR KATHRYN MANNIX

*The thought of death makes many of us feel frightened, so we barely talk about it. But dying is far gentler than Hollywood would lead us to believe*

**"At the end of life, there's an exhalation that just doesn't get followed by an inhalation. As simple and gentle as that"**

**H**ere's a delicate truth: we're all approaching the ends of our lives. Every day counts us down, it's just that most of us rarely talk, or even think about it. And when we do, we feel scared of pain and panic and feeling out of control; afraid of sadness and saying goodbye; worried about deaths we've seen on TV or in films.

I've worked in palliative medicine for over 30 years, helping to improve the conditions of those nearing the ends of their lives. I've sat by the bedsides of scores of dying people and it's taught me a lot about the realities – and misconceptions – of death.

More than half a million people die in the UK each year and almost all of them from a condition that gives at least some warning that death is approaching. If you knew you had limited time left to live, what would you want to do? Who would you want to be with? Are you keen on hospitals? Could your home be suitable? What's your opinion about being kept alive on a ventilator, even if you're unlikely ever to regain consciousness? How much treatment is too much? Are you an organ donor?

My Christmas present to you is some good news: death is almost certainly not going to be as bad as you think. Just like birth, death follows a predictable pattern. Initially, illness reduces people's energy levels. The mechanisms are complex, but the outcome is that they need more sleep. Naps help, but energy is quickly used up, and another snooze is required.

As time goes by, those naps last longer and change in character. Although the person doesn't notice any difference, they dip into unconsciousness for a while, so we're temporarily unable to wake them. At this point, it's time

to switch any symptom-managing medications to a subcutaneous route like a syringe pump, to stop any symptoms from coming back if we cannot rouse the patient when their medicines are due.

If their illness isn't affecting their thinking, then a dying person will still appreciate their family and friends when they're awake, the occasional sip of fluid, perhaps a spoonful of something tasty, although people rarely have much appetite. They may stay in bed. They may appreciate peace and quiet, or their favourite music (I'd prefer BBC Radio 4, by the way). The periods of unconsciousness get longer and, eventually, the dying person is simply unconscious all of the time.

Now, the next change begins: in deep unconsciousness, breathing is driven by the only part of the brain still functioning. This produces an automatic breathing pattern that cycles between deep, sometimes noisy breathing and very shallow breathing. The rate also alternates between fast and slow; there





can be gaps that are several seconds long. Saliva may gather in the throat, causing air to bubble through the fluid, which makes a rasping or rattling noise. These noises are a sign of deep unconsciousness, not of distress.

At the end of life, during a phase of slow, shallow breathing, there's an exhalation that just doesn't get followed by an inhalation. As simple and gentle as that. Sometimes so gentle that the family around the bed doesn't notice. No pain or panic; no sense of loss of control. This is what the vast majority of people experience.

By knowing this gentle pattern, dying people can make choices about where and how to be cared for. Their families are often asked to report dying people's wishes. Do you know the answers? Does your family know yours?

---

Dr Kathryn Mannix is a palliative care physician. The paperback version of her book *With The End In Mind* is out 10 January (£9.99, William Collins).



# 2

## THE 'REAL' YOU ISN'T REAL

WORDS: DR GIULIANA MAZZONI

**W**hen I first met LC, she was 25. She had a beautiful memory, I was told, and beautiful memories are my research hobby. LC could remember her life as a rich, flowing narrative: the colours of her clothes, her exact conversations, the minutiae of her daily routine. But there was a glitch. Her beautiful memory spanned only between the ages of 9 and 14, and it only covered events related to her devout Catholic faith. During those times, she could remember everything, but the rest was as scattered and vague as it is for any of us.

LC's case may seem peculiar, but she was just doing an extreme version of what we all do every day: building a story of

ourselves in order to give us a sense of who we are in the present, but the past we remember is not always a truthful representation of

what has actually happened. Her memory has been marred by psychological problems, and now she was unwittingly building a personal history – some of it real, some of it not – that could explain her sufferings.

Indeed, research has shown that we are all constantly picking and choosing memories, based on our current needs and goals. This is carried out without our awareness, by a psychological mechanism called the 'monitoring system'. Think of the last time a particular sight, smell or

sound brought an image or concept to mind – psychologists call these 'involuntary memories'. Your monitoring system tells you whether this recollection 'feels' like a memory (how detailed and emotional it is), and whether it fits into your current idea of yourself (how 'plausible' it is). If it fits, it becomes part of your story; if it doesn't, it's neglected – for the time being.

LC's memories covered 500 pages, maybe more. "I remember it so well,"

she said, "riding a bicycle in my violet and pink dress, falling off and scratched my leg." It's impossible

to know if it actually happened, but our assessments showed that she was making many of them up. LC wasn't lying, though. We all have apparent recollections of events

that never actually happened. The eminent neurologist Oliver Sacks had a vivid memory of the London Blitz... but he wasn't even in London at the time. In a 2010 study at the University of Hull, we found that 20 per cent of participants had at least one memory that they no longer believe happened to them. These false memories are the result of our brains' ability to imagine possible (and impossible) scenarios – perhaps based on something that actually happened to us, or just invented entirely. The vividness of the mental images, and their emotional intensity, trick the monitoring system into labelling the image as a real memory.

So the past we remember is not entirely truthful. But this is no bad thing. Memory is there to provide a consistent, plausible sense of self that helps us negotiate the ups and downs of life. A not-so-truthful past achieves this goal. Problems arise only when there's an extreme discrepancy

between our memories and reality, as well with our selective memories. Our identities might be fabricated, but we'd be lost without them.

Prof Giuliana Mazzoni is a psychologist and memory expert at the University of Hull.



# 3

## WE LIKE BEING LIED TO

WORDS: DR CHRISTIAN JARRETT

*We can blame our insatiable love of novelty for the rapid spread of harmful fake news*

Mark Twain said that a lie travels halfway around the world while the truth is still putting its shoes on. Actually, that itself is a lie – Twain probably said no such thing and the true origins of the quote remain murky. Nonetheless, thanks to recent research into the spread of (mis)information on Twitter, we now know that lies spread more rapidly than facts – and it seems mostly to do with our appetite for novelty.

In a study published in early 2018 in the journal *Science*, three researchers at MIT analysed around 126,000 stories tweeted by around three million people between 2006 and 2017. Crucially, these stories had all been verified as true or false by six fact-checking websites, including [snopes.com](http://snopes.com) and [factcheck.org](http://factcheck.org). By comparing the tweets, the researchers found that the lies travelled faster and farther than the truth. For instance, true tweets rarely reached more than 1,000 people, whereas the most widely shared false tweets reached as many as 100,000 people. Falsehoods were 70 per cent more likely to be retweeted than the truth, and it took true tweets six times as long as lies, on average, to reach 1,500 people.

A possible explanation for this spread of misinformation was that the lies were being disseminated by more popular or active Twitter users. But the researchers

found the opposite to be true: the typical user involved in spreading falsehoods tended to have comparatively few followers and showed relatively little activity on the site. We can't blame bots (automatic accounts) either – the results held true even after the researchers re-analysed their results with tweets by bots removed.

So what was it about the false tweets that made them so shareable? Analysing the content of the tweets themselves, the MIT team found that lies tended to be more novel and exciting than the truth. The lies were also better at triggering an emotional response – tweets that users sent in reply to a lie often contained words conveying their surprise or disgust.

"It's well known that novelty attracts human attention ... novelty encourages information sharing not only because it's more surprising and valuable – so we think our peers will appreciate receiving it – but because it conveys social status on the sharer, who is seen as being 'in the know' or as having access to unique 'inside information'," says Prof Sinan Aral who led the study. So not only do lies push our emotional buttons, but sharing them makes us feel good, too.

This research didn't explicitly address the question of why so many of us are fooled by lies in the first place. Presumably we wouldn't share lies so often if we knew they were fake. Alas, decades of research in psychology has shown that we simply aren't that good at judging the information we encounter. We don't like thinking too hard, so we'll jump to conclusions (we are 'cognitive misers'), and we're swayed by superficial factors like how easy it is to understand a claim, how popular it appears to be, and whether it supports our pre-existing prejudices.

So whoever it was who said that lies travel fast was right... now we just need to find a way of stopping them.

Dr Christian Jarrett is a psychology writer and author of *Great Minds Think Big* (1999, Wiley, Blackwell).



## 4

## THE NUMBER THAT HOLDS THE UNIVERSE TOGETHER IS CHANGING

WORDS: MARCUS CHOWN

...the opening sentence of LP  
...The Go-Between is  
...foreign countries  
...they do things differently there." But  
...a similar claim has been made by a  
...group of astronomers. For 20 years,  
...they have been suggesting that the  
...laws of physics in the early Universe  
...differed subtly from today's. And in  
...the next few years, a new generation  
...of astronomical instruments will

of everything.

**T**he opening sentence of LP  
...The Go-Between is  
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...a similar claim has been made by a  
...group of astronomers. For 20 years,  
...they have been suggesting that the  
...laws of physics in the early Universe  
...differed subtly from today's. And in  
...the next few years, a new generation  
...of astronomical instruments will  
...put this controversial claim to the  
...ultimate test. The feature of physics  
...which is claimed to have changed is  
...the 'fine-structure constant'. Known  
...as 'alpha', it dictates the strength of  
...the interaction between electrically  
...charged particles and photons of light.  
...Since such an interaction is the source  
...of electromagnetism, it governs the  
...strength of the electromagnetic force.  
...Alpha is vital to our existence. If it  
...were smaller, the electromagnetic force  
...would be too weak to hold together  
...the molecules of life. If it were bigger,

protons in the Sun would repel each  
...other so fiercely they'd never glue  
...together in the first step of the chain  
...of nuclear reactions that generate  
...sunlight. Plus, stellar nuclear actions  
...could never build heavy elements such  
...as carbon, oxygen and iron.

Alpha is dimensionless, with a  
...measured value of  $1/137.03599971$ . But  
...since nobody has any idea whether alpha

**"The standard  
model of  
particle physics  
is flawed"**

could ever be different, two decades ago  
...Prof John Webb and his colleagues at the  
...University of New South Wales decided  
...to find out by looking at quasars. Quasars  
...are the bright cores of newborn galaxies.  
...Their light has taken so long to reach us  
...that we see them at the dawn of time. As  
...their light travels towards Earth, some of  
...it is absorbed by clouds of hydrogen gas.  
...The wavelength at which such bites are  
...taken out depends on alpha at the cosmic  
...era at which the clouds existed. Webb's  
...team found that over 10 billion years  
...ago, alpha was a few parts per million

smaller than it is today. They have started  
...to extend their measurements, and think

the variation in time growing the further  
...back you go. Critics claim the results  
...are caused by faulty instruments and  
...data analysis.

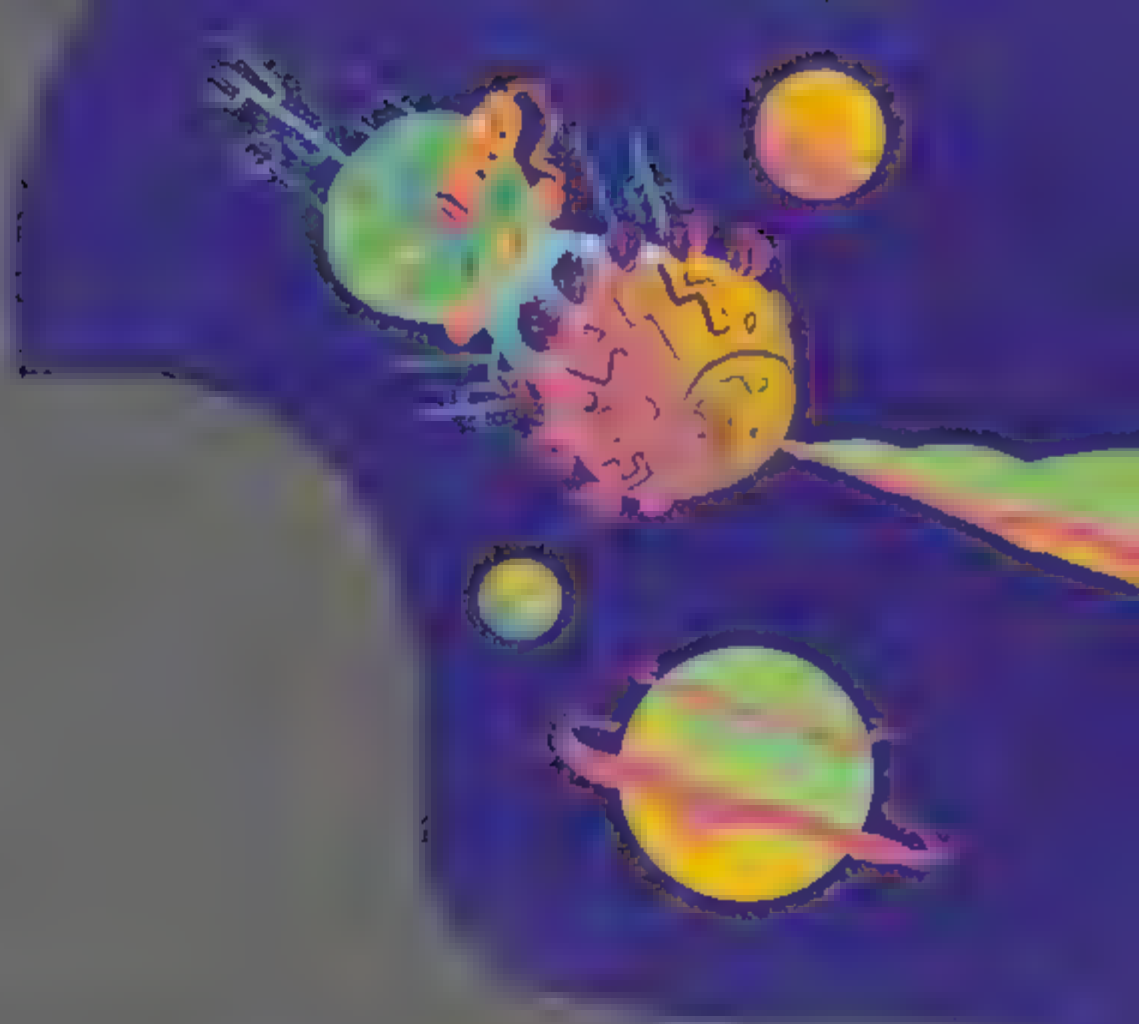
One thing is clear: the standard model  
...of particle physics and the standard model  
...of cosmology are flawed. In the former,  
...the value of alpha is arbitrary, but so too  
...are the strengths of the other fundamental  
...forces and the masses of the fundamental  
...particles. And the latter works only with 98  
...per cent of the mass-energy of the Universe  
...in the form of invisible 'dark matter' and  
...'dark energy', whose identity is unknown  
...and is predicted by no theory. "Physicists  
...are desperate to find an observation that  
...contradicts their current theories and so  
...points the way to a deeper, better theory,"  
...says Webb. "The alpha discrepancy may  
...be just that observation."

Webb is enthusiastic about a new  
...spectrograph which will be attached to  
...the James Webb Space Telescope in Chile. It should improve the  
...accuracy of measurements and minimise

"Then I can get onto something else."

"How has he kept going all these years?"  
..."Fuller's London Pride helps," he laughs.

Marcus Chown is the author of *The Ascent Of Gravity*  
... (£9.99, Weidenfeld & Nicolson).

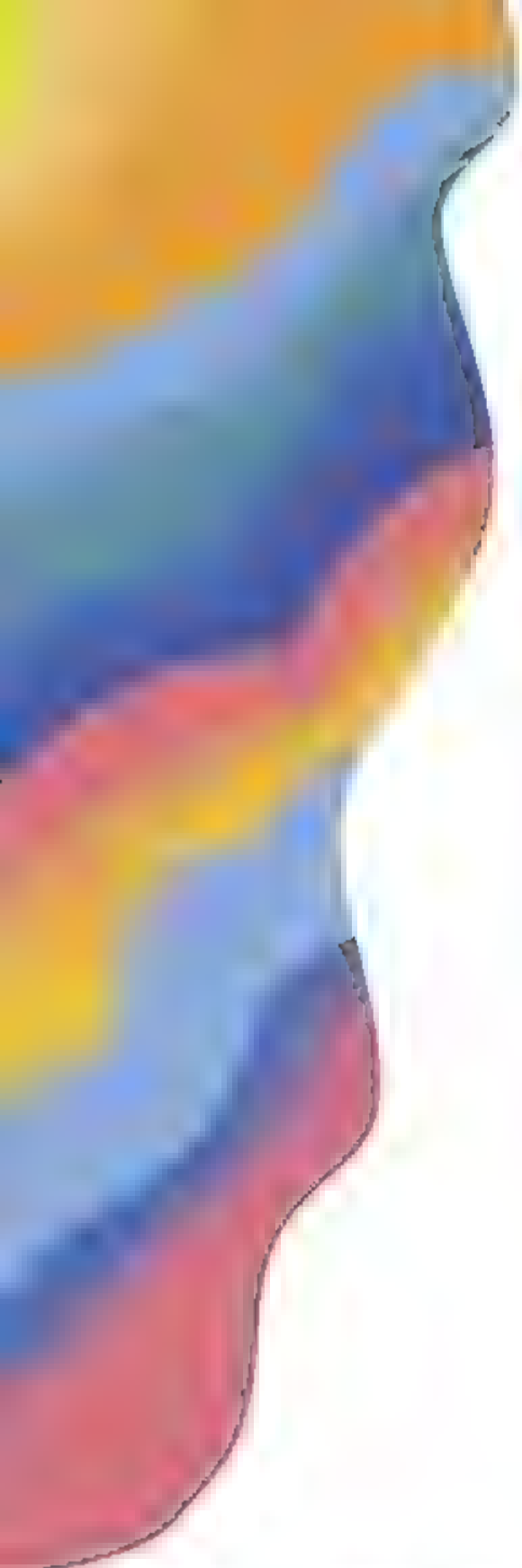












# 5

## WE CAN CHANGE EVOLUTION

WORDS: DR JV CHAMARY

*By using gene drives to tweak the DNA of organisms, we could eradicate diseases, reduce the use of toxic pesticides and halt invasive species in their tracks*

**“We could get around the restrictions of natural selection and accelerate evolution using a ‘gene drive’”**

**N**atural selection only makes features more common if they help organisms survive or reproduce. But we could get around that restriction by accelerating evolution using something called a ‘gene drive’

Gene drives are bits of DNA that work by breaking the laws of inheritance. Many organisms inherit genes on pairs of chromosomes, one from each parent, so their offspring have a 50/50 chance of inheriting either the maternal or paternal copy of any given gene. But a gene drive can copy-and-paste its DNA sequence from the chromosome carrying it to the other chromosome, ensuring the drive is passed on to 100 per cent of an organism’s offspring. Over multiple generations, the drive rapidly spreads through a population’s gene pool.

The prospect of modifying an entire population was once limited by naturally occurring drives, which can only copy-and-paste themselves to certain locations. But by using a gene-editing system called CRISPR, scientists can design artificial drives to target a specific DNA sequence. Such an achievement was unthinkable a decade ago. “No one even imagined that we might be able to readily edit entire species,” says evolutionary engineer Dr Kevin Esvelt of MIT. Esvelt built the first CRISPR gene drive in yeast and showed you can target and overwrite a previous modification, meaning the effect of a gene drive is reversible.

Gene drives could eradicate diseases like malaria, which killed 445,000 people in 2016. Malaria is caused by blood parasites transmitted to humans via bites from infected female mosquitoes. One approach is to suppress insects by blocking reproduction. This is being tested in the lab by the Target Malaria project led by geneticist Prof Austin Burt and immunologist Prof Andrea Crisanti of Imperial College London. In 2018, the researchers used gene drives so that female mosquitoes became infertile and, after eight generations, the captive population crashed. In the wild, this ‘suppression drive’ could collapse mosquito numbers below the level that’s necessary to sustain malarial parasites.

Drives could also protect organisms. In farming, an ‘alteration drive’ could genetically alter pests so they dislike the taste of crops. This would eliminate the need to spray fields with toxic pesticides. In wildlife conservation, gene drives could attack invasive species – like rats, a major cause of extinction on islands – that threaten endangered organisms.

But gene drives could cause harm. A mathematical model built by Esvelt’s team predicted that a drive that spreads indefinitely will escape beyond its target population (due to animal migration, accidental or deliberate release) to other areas. Unless you’re aiming to drive species extinct, it’s better to deploy a self-limiting drive with temporary – and likely local – effects.

Despite potential risks, Esvelt says we should be excited about gene-drive technology. “It’s a way of using nature’s tools to solve ecological problems.”

Dr JV Chamary is a science journalist with a PhD in evolutionary biology.

6

BACTERIA  
CONTROLS THE  
WEATHER

[WORDS: TOM IRELAND]

*Could we end the threats**from drought and flood**on demand?*

**B**acteria do many things for us, from making fuels to breaking down waste. But research suggests they could also determine whether or not it rains.

The microorganisms that affect weather are known as ice-nucleation

agents. They can cause frost on crops and can cause plant disease. They have special proteins on their surface that help water in the air turn to ice at slightly warmer temperatures—around  $-3^{\circ}\text{C}$  instead of  $-5^{\circ}\text{C}$ . On the ground, these proteins can cause frost damage to crops. But when the bacteria are blown into the sky, they can cause ice crystals to form in the atmosphere—a crucial first step in the creation of rain or snow. The process, called ‘bioprecipitation’, was once thought to play only a small part in causing snow or rain. But the impact of

these organisms is now being studied in more detail.

at the Institute for Agricultural Research.

“It’s a new thought,” says Morris. “We now know that when ice forms at warmer temperatures,

it can turn into lots more ice crystals—so there is a multiplying effect.”

There is even tantalising evidence that

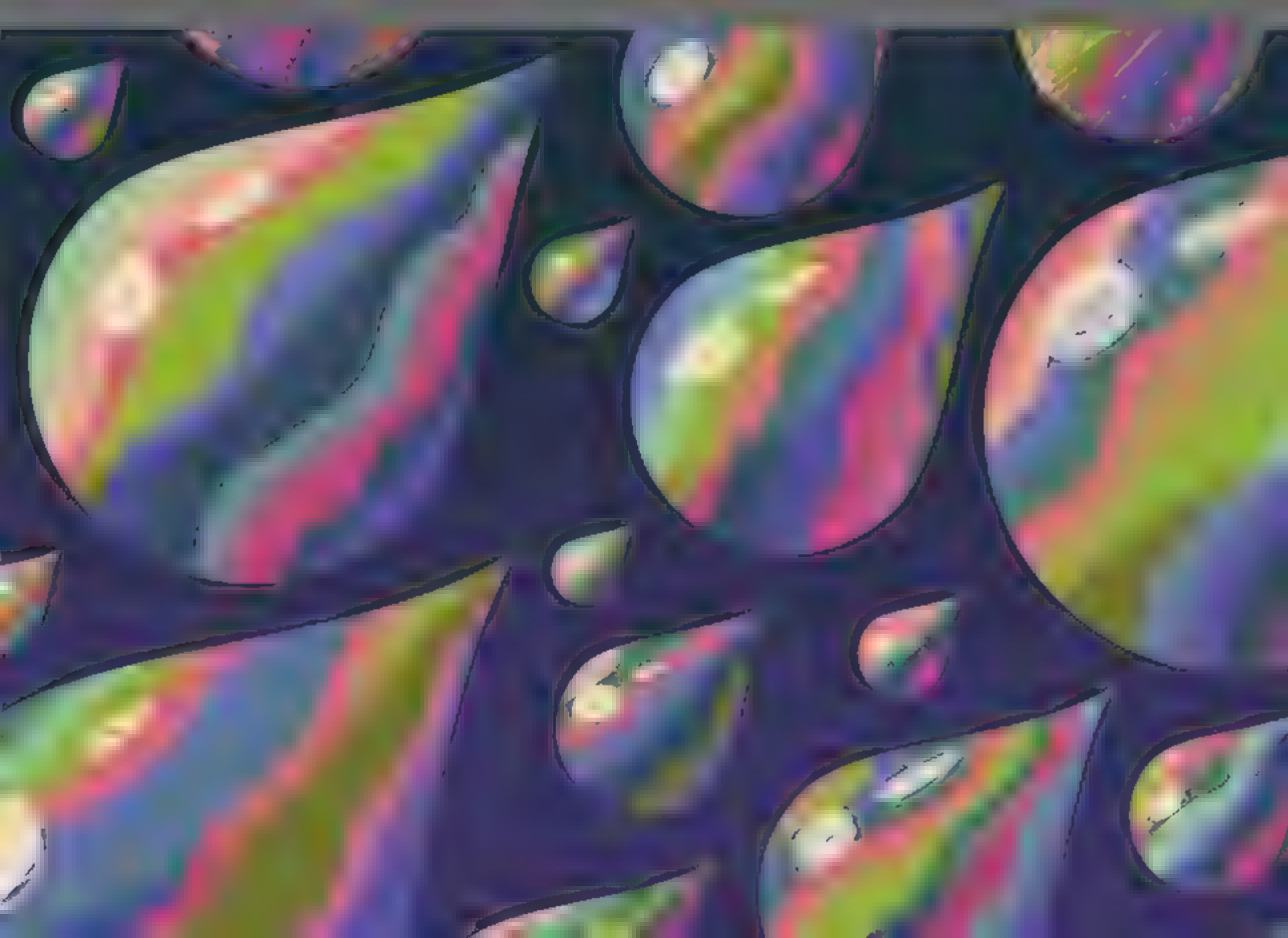
these bacteria can be used to control the weather.

Morris. “We’ve found bacteria in a creek in the New Zealand wilderness that was

the cause of the cantaloupe blight in France.”

Microbes with rain-causing properties were thought to have evolved long before

any organism like a bacterium and you





**"When the bacteria are blown into the sky, they can cause ice crystals to form – a first step in the creation of rain or snow"**

get wafted up into the air and into the turbulence, you're done for – gravity has no effect and you just keep going up," says Morris. "The only way down is in a raindrop. The chances of being hit by a raindrop are very small, so you need to form one yourself."

So given how effective these bacteria are at forming rain, could we use them to seed clouds and create rainfall where it is needed? According to Morris, we

can. She says that large expanses of crops can cause huge numbers of these bacteria to be blown into the air. She believes that by colonising mountain slopes with plants, directly below currents of wet air high in the sky, we could help create rainfall in areas in desperate need of water, such as California. "But it's not simple," she

says. "We need to know exactly what we're doing."

These bacteria also cause disease, so it's about a balance between driving rain and causing disease.

What's more, 'seeding clouds' is a fine art – too many ice-nucleating particles can actually 'constipate' a

cloud, leading to disputes between nations 'taking' others'

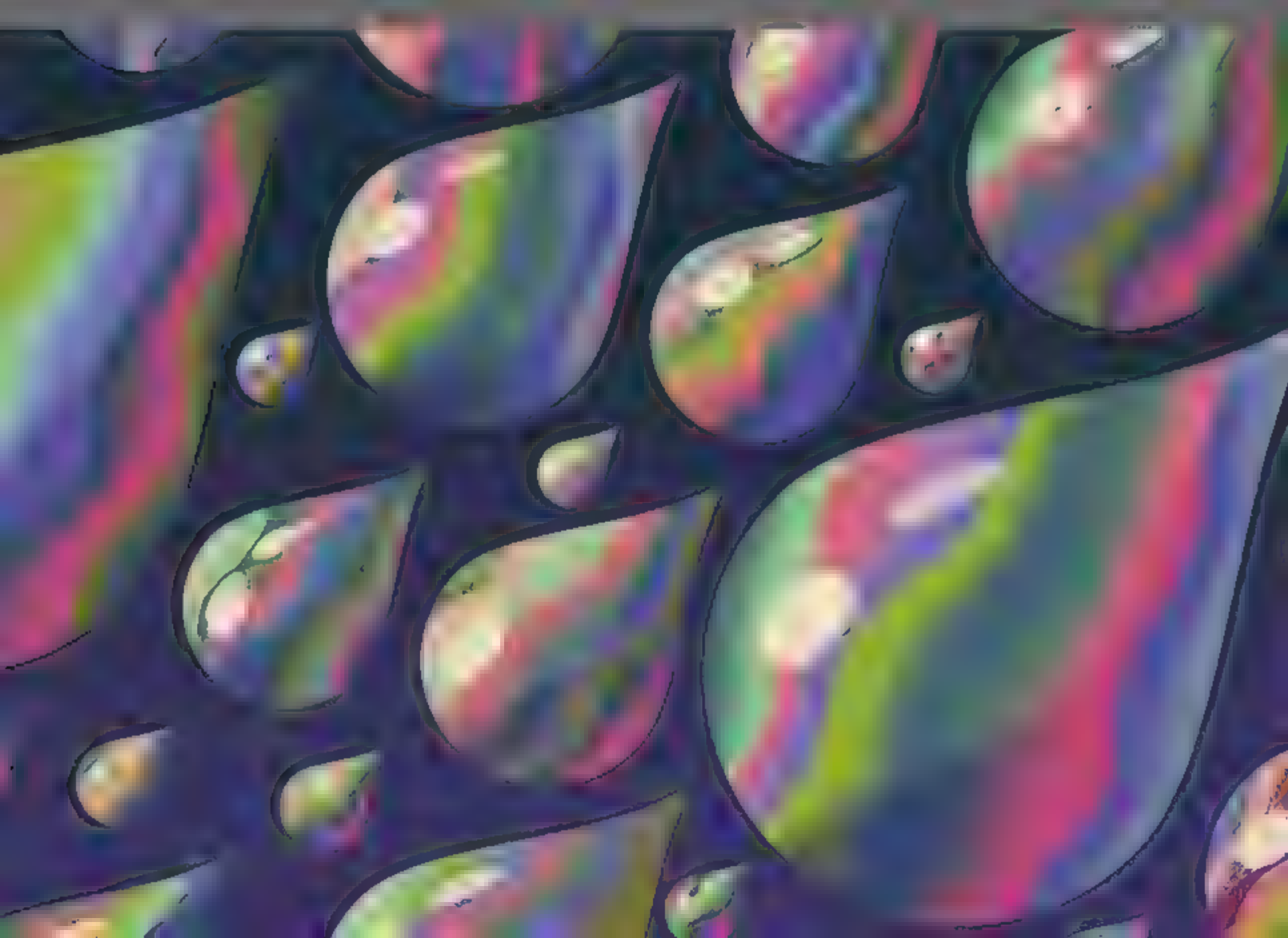
clouds. "We need to know exactly what we're doing."

While before we can truly make it rain –

changing, just think, next time you feel

a microbe returning from an epic journey.

**Torn Ireland** is a science journalist and managing editor at the Royal Society of Biology.



## 7

DIETS MAKE  
YOU FAT

WORDS: ANTHONY WARNER


*It's pointless putting yourself through the misery of calorie counting, as your body shape will always be dictated by your genes*

As someone who writes about food and health, I'm sometimes asked what the modern equivalent of the health crisis caused by smoking will be. What are we doing now that we will look back on in horror, and ask ourselves how did we not see the harm?

My answer is dieting. I believe that in 50 years' time, our grandchildren will ask us why we thought that short-term starvation was an effective way to permanently alter our weight. And they might also ask us how we became so obsessed with making the wonderfully diverse set of human bodies exactly the same shape and size.

In the UK, almost half of us will have attempted a weight loss diet over the past year. Studies suggest that almost all dieters will eventually regain any lost kilos, with most ending up heavier than





before. Long term behavioural studies have shown dieting to be one of the strongest predictors of future weight gain. Work on twins indicates that this effect might be causal; our obsession with reducing fat is ironically causing us to become larger.


Although the media would have us believe in the infinite malleability of the human form, body fatness is rarely within our control. Our genes have repeatedly been shown to be one of the most powerful predictors of how much we weigh, and when food is freely available, weight is one of the most heritable characteristics ever studied, in much the same ballpark as height. There are many physiological systems that contribute to this. For instance leptin is a substance produced by our fat tissue, and as we lose weight the level of this powerful hormone starts to fall. This signals to primitive parts of our brain, powerfully driving us to eat more. Although longer timescales give us an illusion of control, this urge to eat is much like our need to breathe. We can exert control over it for days, weeks, or perhaps even months. But eventually, hunger will win.

To make things worse, hormones can drop our metabolic rate in response to a lack of food, shutting down non-essential functions to save calories. These systems evolved long before celebrity diet gurus, and can't tell the difference between the latest diet and life-threatening famine. It's not much fun: this calorie conservation is likely to cause lethargy, mood disorders, low immune function and a reduced sex drive.

These rounds of failure can also cause psychological harm, with unsuccessful dieters cast as failures in a world that places thinness and physical conformity as the ultimate goal. Instead of treading

**“Although the media would have us believe in the infinite malleability of the human form, body fatness is rarely within our control”**

a well-worn path to failure, we might be better off thinking about what, other than weight loss, might improve our health. Exercising, eating higher quality food, stopping smoking, improving sleep and reducing stress all have the potential to make us happier and healthier. But in a society obsessed with fat, such things are often cast aside as trivialities if they do not cause weight to be shed.

Fat is seen as the only problem, and countless chancers line up to sell us their wares. All diet gurus claim they have the one true solution, and promise to finally fix our errant bodies. But perhaps the real problem is not that we are yet to find the correct diet. Maybe it is simply our refusal to accept that temporary starvation is just not an effective way to improve our health. 

Anthony Warner is a chef and food writer known as The Angry Chef. His latest book *The Truth About Fat* is out in January (£14.99 OneWorld).

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W

e open on a dimly lit room, with a woman standing before a shiny black table. "My name is Maria and I was asked to be your home decor consultant today."

she says in soft, sing-song voice. Dropping to a whisper, she adds: "I'm going to show you different techniques and different ways to fold towels." Over the next 18 minutes, she slowly and carefully fulfils that promise, explaining several towel-folding techniques. But nobody is watching this particular YouTube video to learn how to fold towels. They're watching it to experience a sensation known as ASMR.

"It stands for Autonomous Sensory Meridian Response," explains Dr Giulia Poerio, a psychologist at the University of Sheffield. "It's a term used to describe a sensation that some people experience in response to set triggers." The sensation originates in the scalp as a tingling feeling, and spreads down the rest of the body through the spine and the limbs. "It's often associated with feeling very relaxed and calm," says Poerio.

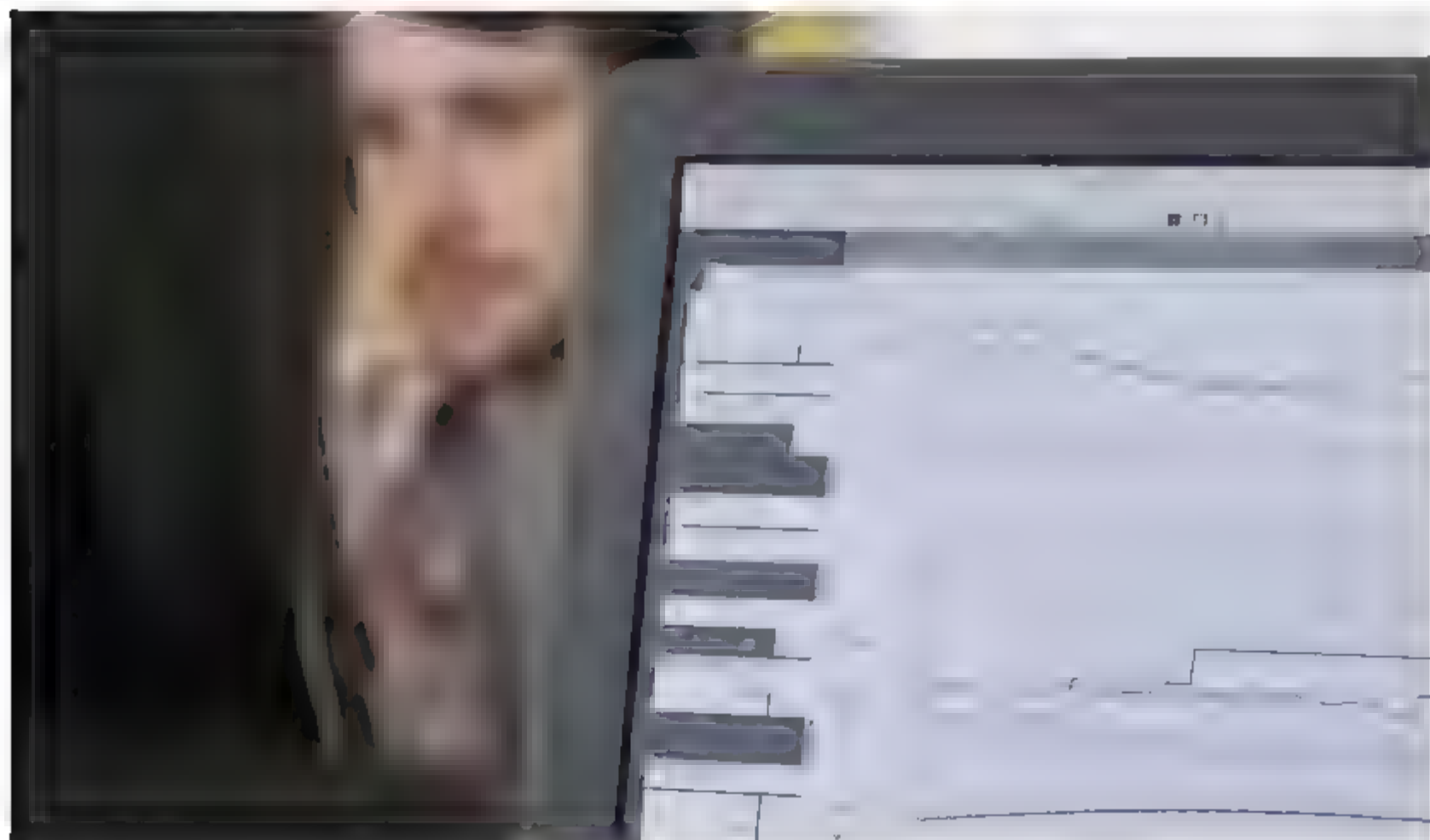
The things that cause ASMR are different for different people, but commonly reported triggers

**"It originates in the scalp as a tingling feeling, and spreads down the rest of the body"**

include whispering, soft speaking, close personal attention, delicate hand movements and gentle tapping. "People typically remember it from experiences in their childhood," says Poerio. "Like getting shoes fitted for school, or lice checks. You can find lice check ASMR videos on YouTube." Indeed, YouTube is full of videos of people who refer to themselves as 'ASMRtists' simulating situations that they hope will trigger ASMR in others, and many of these videos have millions of views. In one of Poerio's research papers, she describes how eclectic these videos get, "from simulations of haircuts, massages and medical examinations, to careful dissections of fruit and vegetables, the squishing of packets of Haribo sweets, and the fondling of bubble wrap."

It's possible that humans have been experiencing ASMR since long before we became human. "If we think more globally about what triggers ASMR, it's grooming actions," says Dr Nick Davis, a senior

BELOW Dr Giulia Poerio's research showed that some people experience a physiological response when watching ASMR videos



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ABOVE and  
 INSET: See?  
 We're not so  
 different!  
 Primates, just  
 like humans,  
 may experience  
 ASMR when  
 being groomed  
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 ASMR may go  
 way back in our  
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lecturer at Manchester Metropolitan University. "You can imagine a gorilla is experiencing something similar to that when a lower status gorilla is grooming them. I wonder if it's related to something much more basic in our make-up." Indeed, descriptions of experiences that sound very like ASMR can be found in literature. A passage from Virginia Woolf's novel *Mrs Dalloway* describes a nursemaid speaking "deeply, softly, like a mellow organ, but with a roughness in her voice like a grasshopper's, which rasped his spine deliciously and sent running up into his brain waves of sound."

#### HEAD ORGASM

The modern phenomenon of ASMR as a leisure activity can be traced back to approximately 2007, when the first descriptions of ASMR appeared on forums like SteadyHealth.com and IsItNormal.com. "Weird sensation feels good", was the subject line of one early posting, where a user named okaywhatever51838 described experiencing a sensation "in my head and all over my body" when watching a puppet show, or when a friend drew on their hand with marker pens. "I'm not complaining, 'cause I love it," they wrote. "But I'm just wondering what it might be... help."

People who identified with those posts gathered into a Yahoo! Group called the Society of Sensationalists in 2008, and by this point, people were already uploading ASMR style videos to YouTube, usually with titles that referred to 'whispering'. Various names were proposed in the discussion groups, including

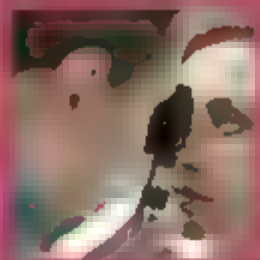
#### WHAT GIVES YOU TINGLES?



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• AIHO (attention-induced head orgasm) or AIOE (attention-induced observant euphoria), but it was a woman named Jenn Allen who coined the term ASMR in 2010, founding a site named [asmr-research.org](http://asmr-research.org).

Since the term 'ASMR' became accepted, the community has grown exponentially and caught the eye of researchers like Poerio and Davis. "In 2013, I was at a conference, and there was a really boring speaker, but she had an amazingly relaxing voice," says Poerio. "I spoke to my colleague afterwards, and was like, 'oh, her voice is just so relaxing. It made me feel all tingly.' And she replied, 'That sounds like this weird thing that I heard on the radio about people getting really relaxed by watching towel-folding videos.' So I went and Googled it, and spent the whole evening watching ASMR videos." The next day, in the office, she hunted for any academic literature on the subject, but found nothing. "I started speaking to different people about it, and I started thinking, 'what would it take to get people to really take this seriously?'"

One of the first scientific papers to be published on the subject was by Davis and his colleague Dr Emma Barrett in 2015. "We published the first peer-reviewed study into ASMR, which described the phenomenon, and how people used it for relaxation and to alleviate low mood," says Barrett. "Those who were depressed reported a stronger boost from ASMR than those who were not. That sparked our curiosity about the possibility of ASMR use in a therapeutic setting."

At the same time, Poerio was conducting studies of her own. "We showed people a range of videos," she says. "We showed them spoken ASMR videos where somebody's whispering or speaking, and sound-only videos which don't contain any speech, and we asked them about their emotional responses," says Poerio. The results confirmed that ASMR was a real phenomenon. "We found that people who experience ASMR find these videos more consistently relaxing and calming than people who don't experience ASMR." She also found that the spoken videos induce more ASMR than the non-spoken ones.

In a second study, she brought people into the lab to see what was happening physiologically





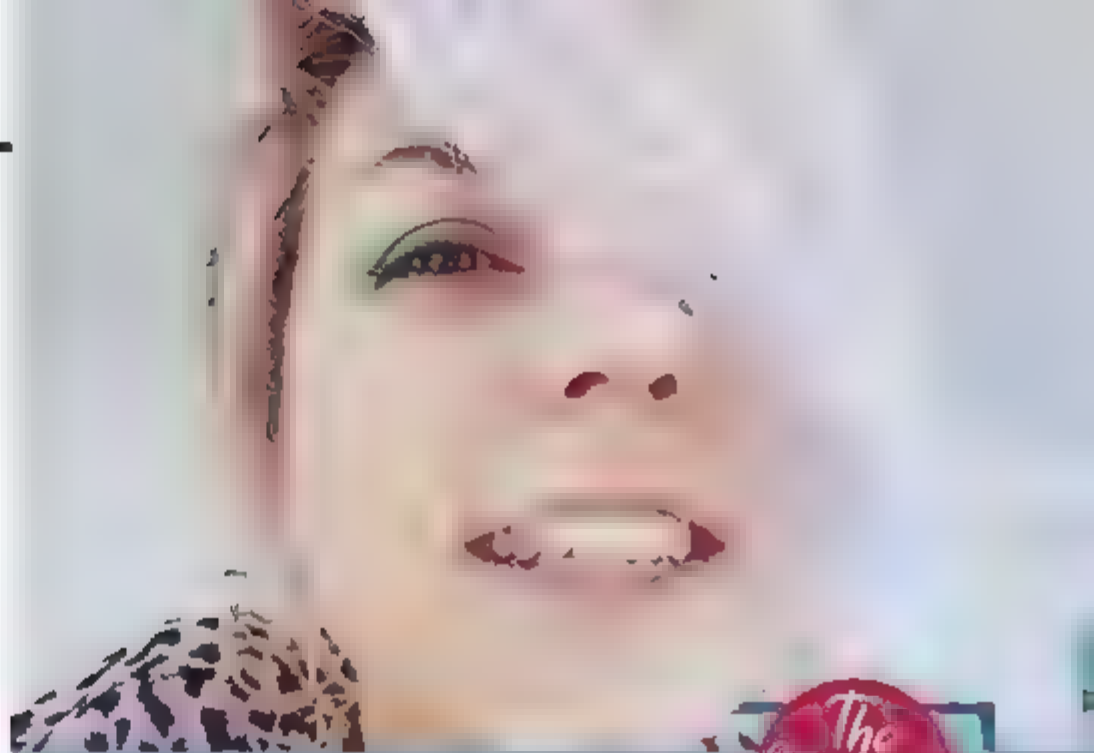
"It's one thing for people to tell us that they're feeling more relaxed, but we wanted to know if their physiology was telling us the same thing as well," she says. They found that people who said they experienced ASMR showed significant reductions in their heart rate while watching ASMR videos, compared to watching control videos. Unexpectedly, however, they also showed significant increases in skin conductance — a measure of emotional arousal. "We think this might reflect the emotional complexity of ASMR," says Poerio. "A blending of seemingly opposing emotional and physiological states."

Studies since have looked at the effects of different triggers, trying to be more precise about what causes the ASMR state. "We're interested in things like whether particular settings might be helpful, or particular object interactions," explains Davis. "[The results] were actually a bit of a mix. But the one thing that was really clear and surprising is that people didn't like background music. That to me is really odd, because we use music all of the time to enhance a mood that you're trying to experience. That doesn't seem to work for ASMR. It seems to distract from the sound of an object being interacted with."

#### RELAXING, NOT RAUNCHY

It's worth noting that there's often a perception of a sexual aspect to ASMR, most likely due to the intimacy of some of the videos. This interpretation is strongly refuted by both the community and the scientists. "In our research study we specifically asked people about their levels of sexual arousal," says Davis. "We didn't find any evidence that ASMR is something that's sexually arousing. Some of the videos you might think have a bit more of a sexual element than others, but in all, I don't think the response that it's eliciting in people who experience ASMR is a sexual one. "I think the community is quite clear that it's not really about that. It's about relaxation. It's about this tingling sensation."

To date, the response from the ASMR community to the scientific work has been positive. "I get quite a lot of people from the public, contacting me and saying, 'thank you for doing this research, it's validated an experience I've had my whole



## "MY HEAD FEELS LIKE IT'S GLOWING"

Listener has been experiencing ASMR since she was young.

Can you describe the sensation of ASMR?

It's like a warm, tingling sensation that starts in the scalp and spreads down the spine and goes up and down. I imagine it as lights going on and off up and down the spine. It's like a warm, tingling sensation.

Do you remember the first time you felt it?

Definitely. I was 12 or 13, and I was the first time I listened to music using headphones. I was lying on my front in bed, and it was dark because the lights were out. I was listening to Christine Aguilera's *The Voice Within*. There's this incredible moment towards the end, it's so passionate and heartfelt and her voice is amazing.

What kinds of experiences trigger the sensation in you?

Really mundane and simple things. To be honest, someone cooking something really competently, when they need to be very precise and you watch it all come together, it's like a masterpiece being created. Pouring drinks is another one, watching people work at a bar. But sometimes

I'll just someone walking through a room well, which is hard to explain, I've even had it from food. At a restaurant in Paris, I was eating an octopus and hummus dish. The texture of it was amazing and made my ears feel all tingly and then the taste was so unexpected and a combination I hadn't experienced before.

Do you seek out ASMR as an experience, or just enjoy it when it happens?

I usually just enjoy it when it happens. Sometimes I'll listen to the same song again when I know I've had the feeling, but it won't always work and it doesn't mind. It sometimes happens with a really weird old story too. When the ending just works so well. I think there's definitely a satisfaction element to it.

Did you think that everyone experienced the sensations?

I thought it was a thing everyone experienced. I think it's more present when I'm in a good place. When I'm happy, I'm very open, and it's all about being open. When I'm not, I feel closed, like I don't want to feel this.


life," says Poerio. The response from the academic community, however, has been more muted. "I think it's really sparked the public interest more so than academics," she adds.

Meanwhile, plenty of questions still surround the phenomenon. The proportion of people who experience it is unknown, and whether there's a binary that you either experience it or you don't, or whether there's a spectrum of intensity. We know that speech enhances the experience, but we don't know whether it's necessary to understand the language of the person speaking. We also don't know whether it has a deep physiological basis, referring back to apes grooming each other, or whether it's something else.

The answers to these, and other questions, could help further validate ASMR as a genuine phenomenon, and even begin to unpick whether it could be useful in a medical context. "It's something that people are already using, and saying that it's giving them a lot of personal benefit," says Poerio. "I think it's really important to mirror that with science, so to try to test these ideas, and see whether they're potentially clinically important."

Davis agrees that the phenomenon has positive potential. "There don't seem to be side effects, as far

## "People are using ASMR to help them cope with things like depression or chronic pain"

as I can see," he says. "It doesn't give you headaches, or give you heart palpitations, and it doesn't seem to be addictive. It makes people happy with no drawback. People are using ASMR to help them cope with things like depression or chronic pain, and we wouldn't want to go so far as to say that ASMR is a treatment for those conditions. But if it can be used to help people who are receiving treatment in another way, then that would be beneficial." 

Duncan Geere is a freelance science and technology journalist

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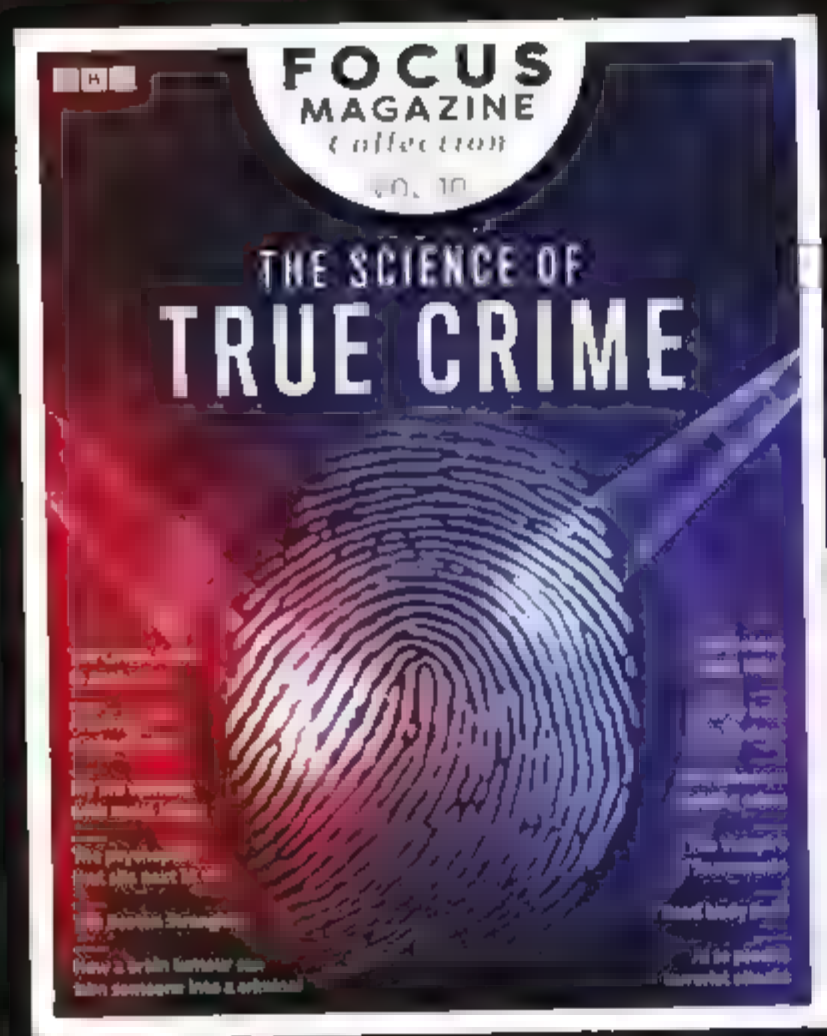
**EMMA WHISPERSRED** videomaker Emma WhispersRed held a live event in New York this summer for ASMR enthusiasts





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based around a  
kimberlite pipe





# EARTH'S HIDDEN OCEAN

Exotic diamonds blasted from deep within the Earth's mantle are transforming our understanding of our planet

WORDS: MIKA MCKINNON

Deep below the surface of our planet, an ocean lurks. It's a secret world of water we only know about because of an unlikely messenger: diamonds.

The rocks we see and interact with every day – mountain ranges, crumbling coastal cliffs, maybe the soft sediments and soils that line valley floors – are only a small portion of all the rocks on Earth. In-between the surface of the planet and the iron-rich core is the mantle, a warm, thick, gooey layer of rocks that flows like plastic. This is where the diamonds grow, hundreds of kilometres down. As the gemstones form, they freeze a moment of deep mantle geology, and when they arrive at the surface, scientists can poke and prod at them to understand more about the conditions within the planet. From the stories those diamonds tell, the mantle is very, very wet, and may contain as much – or more – water than all of the Earth's oceans put together.

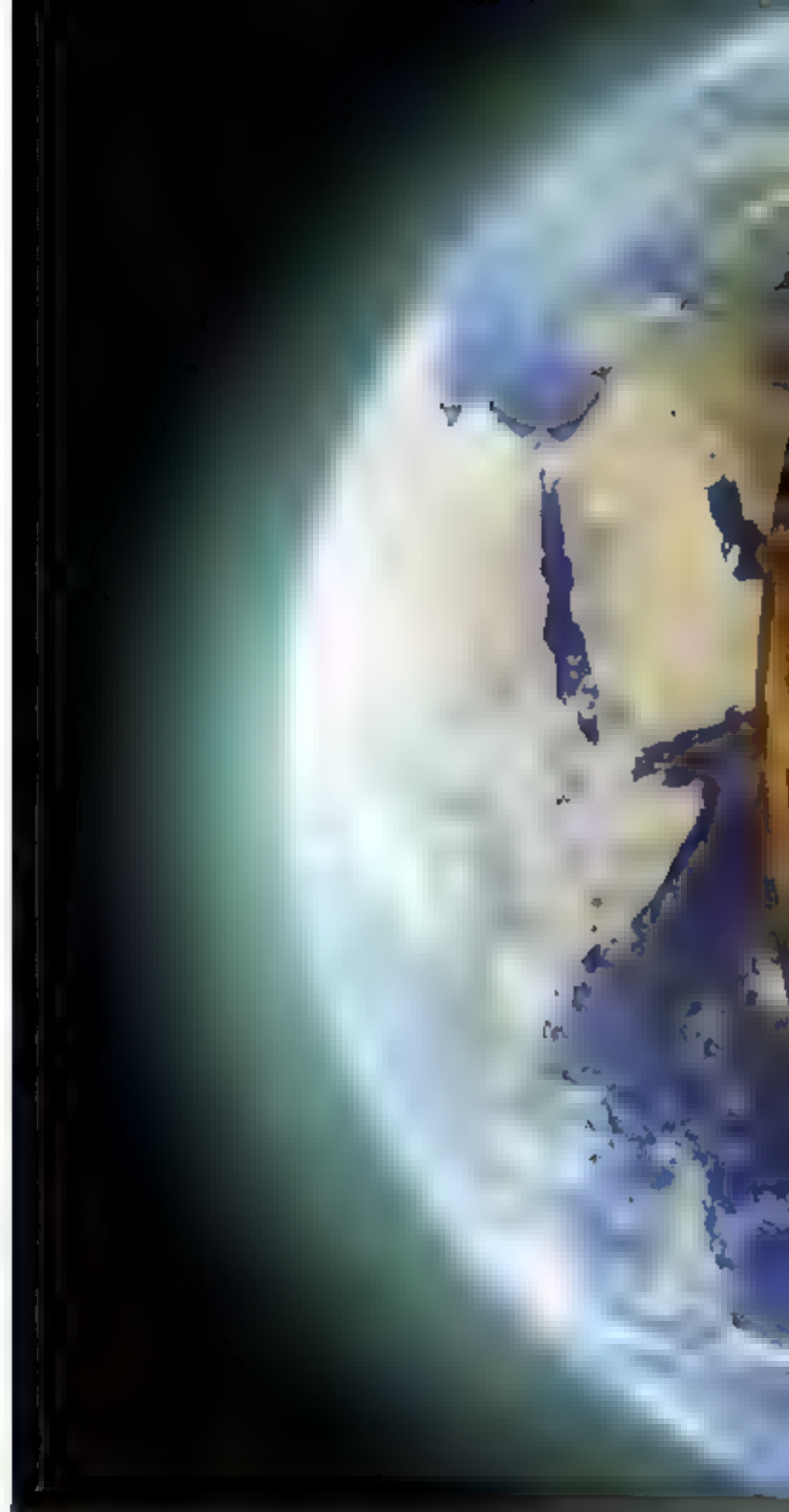
Water is one of the key factors that sets Earth apart from other worlds, and a prime target when hunting for possible life out in the Universe. Could these diamonds offer us insight into the formation of Earth and other planetary bodies?

#### DIAMONDS ARE A GEOLOGIST'S BEST FRIEND

Diamonds can grow as either fibrous snowflakes or layered octahedra, explains geologist Prof Maya Kopylova from the University of British Columbia. When fibrous diamonds form, the long crystal strands catch and tangle with their surroundings, weaving tiny droplets of nearby fluids into their structure. The enormous pressure and

#### SUPER-CRITICAL FLUID

As supercritical fluid forms at specific temperatures and pressures, it has characteristics of both liquids and gases. For example, it can dissolve substances like a liquid. Fluids in this way, dissolving gas and solid

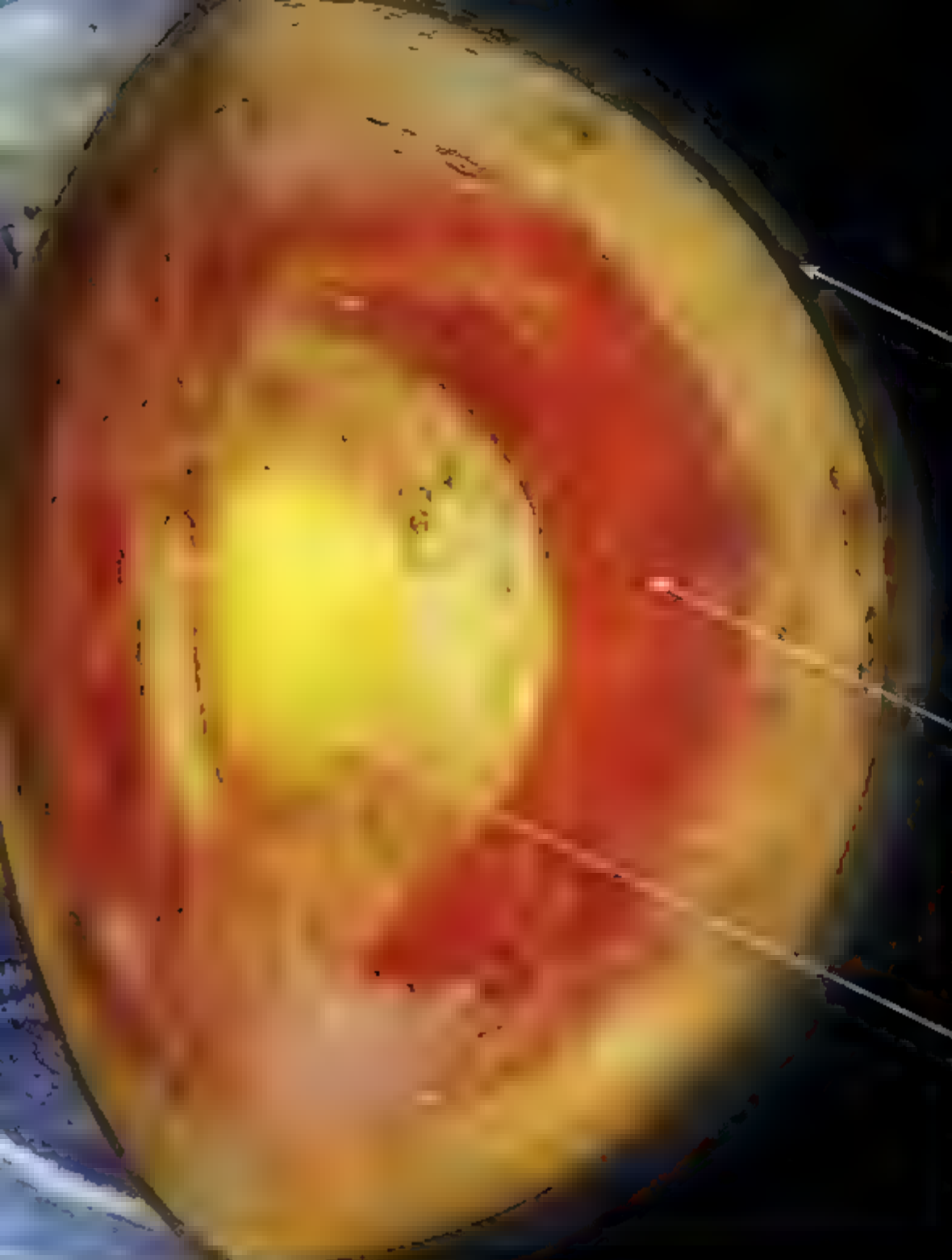


high temperature of the mantle pushes these fluids to a supercritical tipping point between liquid and gas that can dissolve nearby rock and gas. These dissolved substances are then incorporated into a forming diamond to ensnare a perfect, tiny sample of the mantle. "As diamonds grow, they can trap materials that are surrounding them," says Dr Kim Tait, the curator of mineralogy at the Royal Ontario Museum. "This is a great opportunity to directly look at some of the materials that have formed deep within Earth."

These inclusions are minute – fractions of the diameter of a human hair, and rarely visible to the naked eye. While these dark, scruffy-looking diamonds are no good for jewellery, for a geologist they are precious windows into the conditions deep inside Earth. "In a perfect world, we would drill down to the core and take samples of all the material, but that's just not feasible in real life," says Tait. Instead, scientists have to wait for ●

**"From the stories those diamonds tell, the mantle is very, very wet"**





# THE EARTH

## CRUST

0-200KM DEEP

The surface of the Earth is made of rigid yet flexible tectonic plates. Continental plates are old and light, composed of low-density minerals rich in silica. Continental plates average 15 to 30 kilometres thick, although the most ancient plates can be up to 200 kilometres thick. Oceanic plates are younger and denser, composed of high-density minerals rich in iron and magnesium with little silica. At just 7 to 10 kilometres thick, they are thinner than continental plates.

## MANTLE

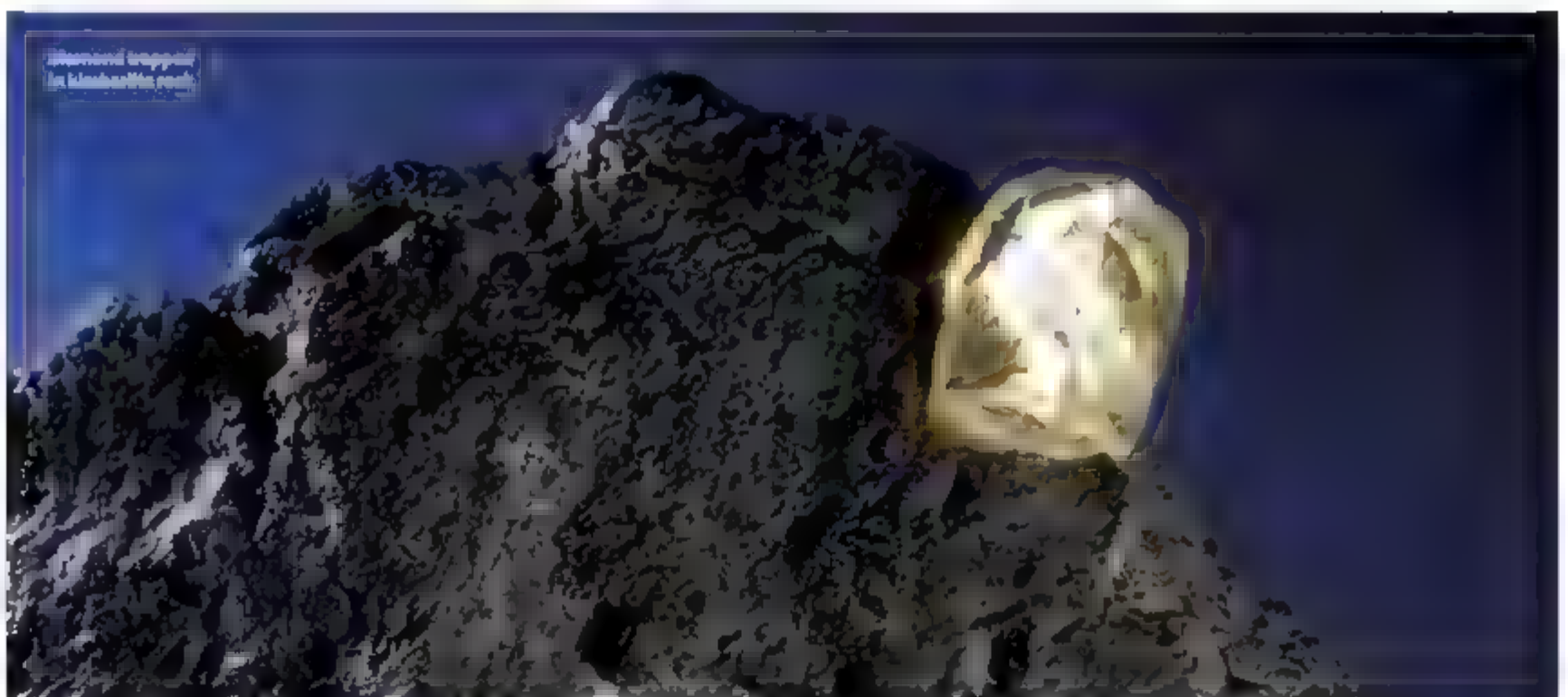
30-2,890KM DEEP

The thickest layer of the Earth consists of hot, ductile rock rich in iron and magnesium. Over millions of years, the mantle flows in enormous convection cells (shown here by yellow arrows) that drive plate tectonics and feed hot spots below volcanoes. Diamonds form in the upper mantle at depths of 150 to 800 kilometres.

## CORE

2,890-6,371KM DEEP

The Earth's iron-nickel core is a solid inner ball wrapped in a liquid outer core that is constantly in motion. This hot, fluid metal generates the planet's protective magnetic field, which deflects the Sun's harmful solar wind.





the diamonds to arrive at the surface by natural geological activity

Yet a diamond's journey to the surface is not simple. If diamonds are slowly carried up from the mantle over millions of years of mountain-formation, they'll degrade into graphite long before they reach us. According to Kopylova, intact diamonds are brought to the surface only by cratons or kimberlite rock formations. Cratons are old, stable parts of the continental plates with little tectonic activity, while kimberlites are a rare type of volcanic eruption that act as conduits extracting magma from the deep mantle directly to the surface. "Kimberlite pipes just shoot from 400 kilometres deep up to the surface within days!" says Kopylova. This express trip from mantle to surface means that diamonds don't have a chance to decompose into graphite. It is for this reason that many of the world's most important diamond mines are based around kimberlite pipes.

This speedy ascent paired with the extreme hardness of diamonds is what makes them capable of carrying snippets of the mantle up to the surface and is why they are so useful for geologists who study the deep Earth. "Diamonds are an insulating vessel that can keep the internal pressure that will be lost in other deep-mantle minerals," says Kopylova. "We can look at garnets, for example, but garnet is not as good at keeping the pressure inside of the crystal still at high pressure. Diamond is unique."

#### ICE, ICE, BABY

For decades, researchers have studied diamonds to

## "This diamond adds a new element to the complicated dance of water within Earth"

help them understand the chemistry and geology deep below our feet. But in March 2018 a team led by Prof Oliver Tschauner, a mineralogist from the University of Nevada, Las Vegas, found something utterly unexpected when they X-rayed a diamond extracted from Africa ice.

When water freezes, it crystallises into ice. But not all ice is like the stuff that we find in snowbanks or ice cubes. Under extreme temperatures and pressures, ice can take on more exotic structures where its hydrogen and oxygen atoms will bond with increasing complexity. Most of what we know about these exotic phases of ice comes from carefully growing samples in laboratories under artificial conditions.



## INCLUSIONS

Inclusions are materials that become trapped inside a mineral during its formation.

Almost all the ice you encounter on a daily basis is hexagonal ice  $I_h$ , with a few traces of its cubical cousin ice  $I_c$  in the upper atmosphere. Scientists first started noticing that ice frozen under higher pressures in the lab took on different crystal structures as early as 1900, with each new exotic variety counting up as ice II, III, and so on. The ice found trapped within the newly found diamond is ice VII. While it is the first time one of these unusual phases has been found naturally on Earth, scientists have long-theorised that particular varieties of water ice might form on other planetary bodies, maybe even within the icy moons of our Solar System. Therefore, by discovering tiny crystals of ice VII within this diamond, scientists have revealed an unexpected link between Earth and other worlds.

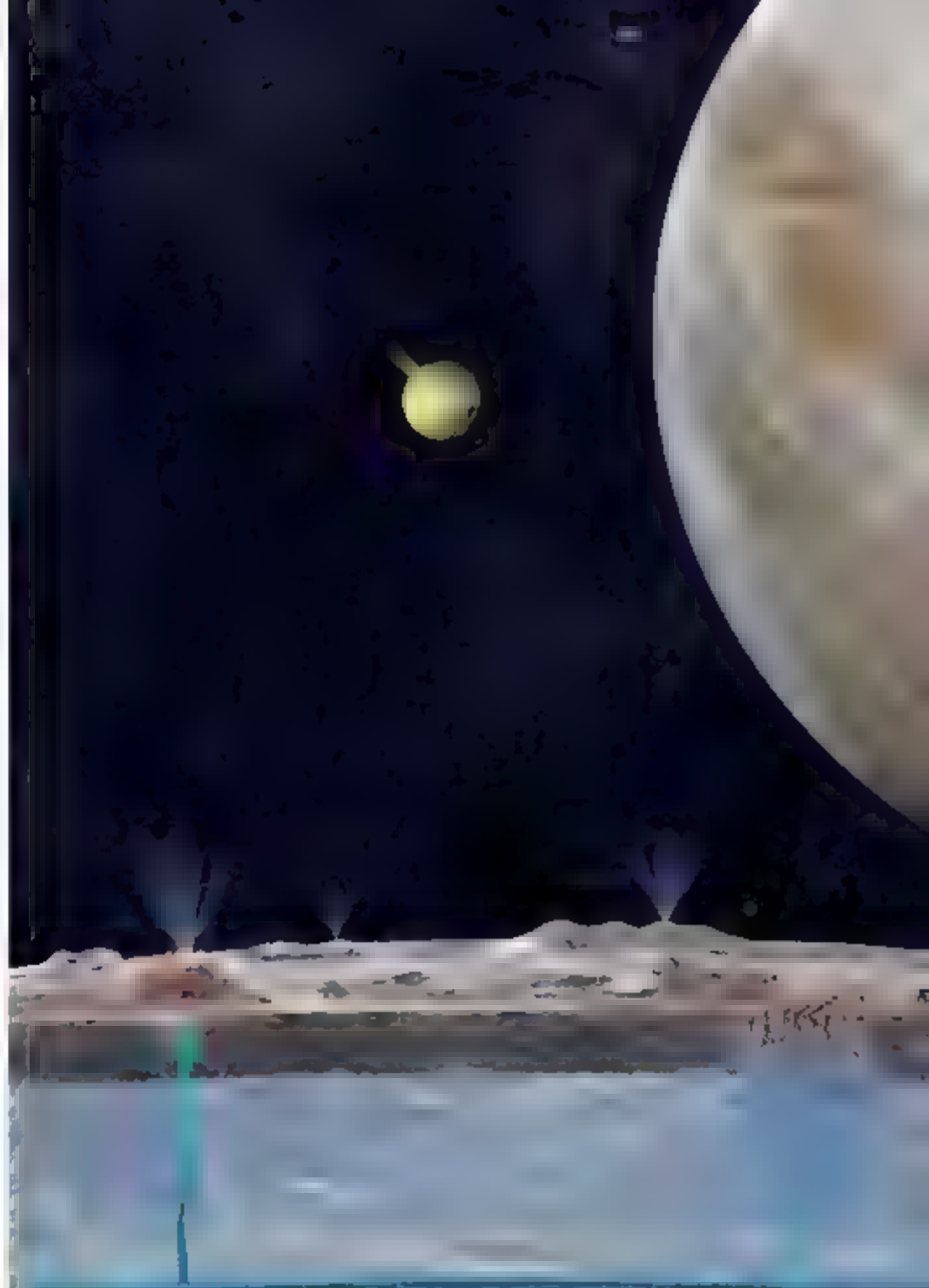
"Ultimately this diamond represents a very unusual form of water that we do not normally see at the [Earth's] surface because the pressure required to make it is simply much greater than the ambient pressures," says Prof George Rossman, a mineralogist at California Institute of Technology.

### LITERATURE

The ice VII didn't form at the same time as its encasing diamond. This fluid was trapped almost like a bubble in the diamond," says Tait, who is responsible for preserving the sample. Originally, as the diamond grew hundreds of kilometres deep within the Earth, the inclusion was a supercritical fluid on the verge between liquid and gas, and was too hot to crystallise into ice. If the diamond had stayed buried within the planet, this is where the story would have ended. But the diamond was expelled from the depths, and dropped into our much chillier surface conditions.

"When the diamond came up to the surface, it still maintained a high internal pressure squeezing the water under pressure somewhat akin to what they were experiencing deep in the Earth," explains Rossman. "As it rose to the surface, the diamond cooled. Only then did the water crystallise into ice VII."

Any time that a new material is discovered, scientists use that first sample as a type specimen that is preserved and protected. The Royal Ontario Museum houses roughly 200 type specimens, including the ice VII diamond. The diamond acts as a tiny pressure chamber keeping the ice VII stable, so the museum doesn't need to keep it cool or take any other special actions to keep it safe. "It's completely stable within its trapped host," Tait says. But that doesn't mean it's just sitting on a shelf. ●



ABOVE: Some scientists think that Jupiter's moon, Europa, could contain ice VII.

## ICE VII

### An exotic type of ice

When water freezes on Earth, it usually forms ordinary water ice, known as ice I. But that's not the only type of ice. Under extreme temperatures and pressures, hydrogen and oxygen can bond in more complex structures, creating over a dozen exotic phases of ice.

In the lab, ice VII can be formed at room temperature, providing that it is exposed to 30,000 times more pressure than we experience on the surface of the Earth. Instead of forming hexagons, ice VII grows as tiny rod-like needles merging into crystal cubes. Scientists tried to imagine environments that paired

both high pressure and low temperature where ice VII might form in nature. While theorised to form Jupiter's frozen ocean moon Europa, or distant watery exoplanets like Gliese 436 b and Gliese 1214 b, naturally-occurring ice VII was first discovered here on Earth within a diamond. Diamonds can incorporate bubbles of fluid as they grow, trapping substances within their crystal structure. As a diamond is so strong, it keeps those inclusions locked within a crystal cage of high pressure, even if it erupts onto the Earth's surface and cools down.



It is unlikely that scientists will find diamonds on planetary bodies, but basalts from volcanic activity could offer primitive hints about the mantles of other worlds.

● in a storage room. "All of our type materials are in a lockable vault because they are that important to us," says Taft.

Despite the astonishing discovery that such an exotic form of ice can form in nature, actually seeing the diamond is a bit disappointing. Taft admits, "Our photographer said, 'Let's take a picture of it.' I showed it to them and they're like, 'Oh.'" Taft laughs. "I wish it was a little bit more exciting to see." Each inclusion is just a few microns large and holds even smaller microcrystals of ice VII and other minerals.

#### PLATES AND PLANETS

While it might not be photogenic, this diamond with its unique passenger of ice VII adds a new element to the complicated dance of water within Earth and other worlds. Like Earth, the rest of the planets in our Solar System were bombarded with comets and swathed in hydrogen gas when they were forming, so they should also have plenty of water locked within the rocks. Yet as far as we know, Earth is the only planet that has plate tectonics to link the water cycle from its surface to its depths. The Earth's crust is made of rigid yet flexible plates that are constantly moving at about the same speed as our fingernails grow. These plates collide and crumple to form mountain ranges but when continent meets ocean, the denser and colder oceanic plate is shoved deep into the mantle, carrying with it cold, wet rocks – and therefore water – from the ocean floor.

"Oceanic sediment is constantly being brought down into the deep Earth where the water from these sediments is released," says Rossman. Then, the water interacts with minerals, either becoming incorporated into their structure or getting trapped as inclusions in diamonds and other crystals. This infusion of water reduces the melting point of the surrounding rock, liquefying it into magma that erupts as volcanoes. By finding an exotic variety of ice lurking within a diamond, we have a unique window into the particular blend of temperature and pressure at depth, a bespoke sample collector offering insight into the heart of our planet.

"If we could take an ice cream scoop and scoop out all of these minerals that have trace amounts of bound water in them, and then squeeze the water out, there is probably as much water in the upper mantle tied up in these minerals as there is in all of the oceans of the world today," says Rossman. "The upper mantle is a reservoir of water, potentially as great as every bit of water we have in the oceans."

The story of water is a vast dance, spanning hundreds of kilometres and billions of years, a story of clouds and ocean and icebergs, but now we know it's also a story of fire and diamonds and ice. ●

Mika McKinnon is a field geophysicist and disaster researcher studying and responding to tsunamis. She is a science advisor to the New Zealand government. She tweets from @mikamckinnon.



# URGENT APPEAL: help Syrian refugee parents like Khitam to protect their children through the winter.



Khitam lives with her four young children, husband Abdelsalam, and his elderly parents in a single, damp room of a half-built apartment block near Tripoli, Lebanon.

There are holes in the walls and ceiling and they share a toilet with other refugee families crammed into the building. Khitam and Abdelsalam are mentally and physically exhausted after years of struggling to survive unable to earn a living and fighting a daily relentless battle to feed their children.

Right now, they are terrified by the prospect of another winter in their cold, uninsulated single room. Another winter where they will feel every blast of icy wind. Another winter where every time their children cough or sneeze they will fear they have contracted a lethal respiratory condition like pneumonia or tuberculosis.

UNHCR, the UN Refugee Agency, needs your

support to help parents protect their children this winter.

**Please will you give £75 to provide a refugee family like Khitam's with a winter survival kit to protect against the freezing weather? The kit**

contains essentials such as a heating stove, thermal blankets and a tarpaulin for insulation. It could mean survival for a family like Khitam's.

Last winter, as a result of their exposed and unsanitary living conditions Khitam and all four of her children became ill. Baby Bilal had a high temperature and diarrhoea. Her sons Khaled (3 pictured) and Abdul Rahman (8) had chest infections and their sister Fatimah (4) contracted worms. Khitam

herself developed painful growths on her throat and lost her voice. Without access to a free healthcare system—like we have in the UK—Khitam became overwhelmed with worry about how to pay for the treatment and medicines her children needed.

**"I felt helpless. My children were coughing and crying and there was nothing I could do."**

Khitam believes that

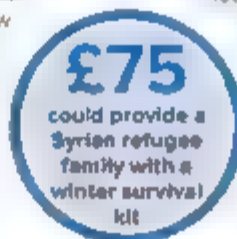
without assistance from UNHCR "my children would be dead".

Across Lebanon and Jordan, six of the last seven winters have brought heavy snowfall and temperatures regularly drop below 0°C. 1.7 million Syrian refugees are living, like Khitam's family, in unfinished or derelict buildings, or in makeshift shelters, sometimes made of little more than wood and plastic sheeting.

*"Living here, in these conditions, I cannot keep my children healthy."*

This coming winter, when temperatures are likely to fall below zero, the lives of the most vulnerable young children, pregnant women and the elderly, are at grave risk from hypothermia, frostbite and diseases like pneumonia.

**With a gift of £75 you can provide a winter survival kit containing a stove, blankets, Jerry can and a tarpaulin to help a family insulate and heat their home. Please give today – you could save the lives of children like Khitam's.**



[unhcr.org/wintersupport](http://unhcr.org/wintersupport)

Call 020 3761 9525

**With £75, you can give a winter survival kit containing:**



**STOVE**

For heating and cooking. An absolute essential.



**TARPAULIN**

For insulation. Keeps the cold out and the warmth in.



**BLANKET**

Families left their homes with nothing. A simple blanket could save a life.



**JERRY CAN**

For storing fuel or water. Means people can avoid venturing out in the cold.

**Yes, I will help Syrian refugee families survive the winter.**



Please accept my gift of: ☐ £75 ☐ £150 ☐ £225 My own choice of £

Please post urgently to: Freepost UNHCR. You do not need a stamp.

Please debit my: ☐ Visa ☐ MasterCard ☐ Maestro ☐ AMEX ☐ Money order

Card no.

Valid from  Expiry date  Issue no.  Master only

Signature  Date

☐ I enclose a cheque or postal order made payable to UNHCR

Please tell us if you are happy to hear more about UNHCR's work ☐ By email ☐ By phone

For more information on how to help Syrian refugees, visit our website at [www.unhcr.org/uk/privacy-policy](http://www.unhcr.org/uk/privacy-policy) or call 020 3761 9525

Title  First name  Last name

Address

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# CAN PARTY DRUG MDMA HELP TREAT ALCOHOLISM?

A pioneering new study in  
Bristol is using MDMA-  
assisted psychotherapy to help  
alcoholics break the cycle  
of addiction

WORDS: RUSSELL DEEKS





A

lcohol is dangerous. Its abuse accounts for around 8,000 deaths in the UK every year, while the societal cost – in terms of the strain on the NHS and the police – is enormous. It costs £3.5bn a year for the NHS to treat alcohol-related illnesses and injuries, while 70 per cent of violent incidents occurring during the evenings, nights and weekends involve alcohol.

Many people are, of course, able to enjoy a drink without coming to any harm, or becoming addicted. But many aren't: it's estimated that 9 per cent of men and 3 per cent of women in the UK show signs of alcohol dependence. And if you do get hooked, the prospects aren't great.

There are many treatment programmes available, but over 80 per cent of people that complete one will be drinking dependently again within four years – and the dropout rate is also high, so the majority of those who seek help won't even complete a treatment programme in the first place.

But a groundbreaking study currently underway in Bristol may offer new hope. The project is exploring the use of MDMA – 3,4-methylenedioxymethamphetamine, or 'ecstasy' – as an adjunct to psychotherapy, to help addicts come to terms with childhood trauma such as neglect or abuse.

Previous studies in the US have shown that, used in this way, MDMA can be beneficial in treating people living with post-traumatic stress disorder (PTSD). Now the Bristol team, overseen by Prof David Nutt at Imperial College London – the former government drugs advisor who, in 2007, was dismissed from his post on the Advisory Council on the Misuse of Drugs after calling for a more evidence-based approach to drugs policy – wants to see if they can achieve similar results working with alcoholics.

#### PART OF THE PROCESS

Let's be clear about one thing. MDMA is not a cure for alcoholism and it's not simply a case of giving patients a bag of pills and they'll forswear the booze overnight. Instead, the Bristol study sees psychiatrist Dr Ben Sessa and clinical psychologist Dr Laurie Hedges researching MDMA as part of a programme of intensive psychotherapy, which is only embarked upon after participants have undergone a detox programme to cure their physical dependency. Sessa and

#### WARNING

Ecstasy (MDMA) is a class A drug according to UK law. Anyone caught in possession of it will face up to seven years in prison, an unlimited fine, or both. More information and support for those affected by substance abuse problems can be found at [bit.ly/drug\\_support](http://bit.ly/drug_support)

# "MOST PSYCHIATRIC MEDICATIONS JUST PAPER OVER THE CRACKS"

● Higbed's programme is aimed at addressing the reasons that drove the patients to alcohol misuse and addiction in the first place.

"I did my initial training in child and adolescent psychiatry. I spent 10 years working in an inpatient unit and came across many young people with developing personality disorders. All of them abused, maltreated as children, carrying around a head full of traumatic memories. Many self-harm, some take their own lives before reaching adulthood and many end up dependent on drugs and alcohol," explains Sessa. "Current treatments for these disorders are very poor. Most psychiatric medications just paper over the cracks. It's like taking paracetamol if you've got a fever – it'll bring your temperature down, but it's not going to kill the bug. In psychiatry, the bug is trauma and the only real cure is psychotherapy."

Many people therefore find themselves turning to drugs and alcohol, which are highly effective at blocking out the pain in the short-term but bring all kinds of new problems with them. But MDMA can help people open up and talk about their most deep-seated problems, so Sessa wants it to be used in conjunction with psychotherapy to provide a better treatment.

## TESTING ENVIRONMENTS

MDMA was first produced and patented in 1912 by German company Merck Pharmaceuticals in an effort to develop an artificial blood-clotting agent. According to

records in the Merck archive, the drug was administered to patients in a Berlin hospital but it took until 1927 for someone to notice the similarity between its chemical structure and that of the hormone adrenaline. That's when the first animal trials were conducted to see if MDMA might mimic the hormone's effect.

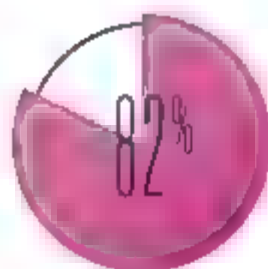
Then in the 1950s, a US chemist called Alexander Shulgin discovered the compound and began to experiment with it as a tool in relationship counselling, which remained its primary use until the early 1980s. But by that point, enough of the substance had leaked out from labs and clinics to be used recreationally that the US government decided to ban MDMA in 1985, putting paid to any genuine research that was being carried out (it had been classified as a class A substance in the UK since 1977).

It's illegality didn't prevent the rave explosion of the late 1980s and early 1990s from taking the drug into the mainstream, however, which is something Sessa isn't entirely happy about. "I see MDMA as a medical tool, and the rave generation as an irritating blip in its history," he explains. "MDMA is a medical compound."

## BRITAIN'S ALCOHOL PROBLEM: IN NUMBERS

£4.8m

The cost to the NHS of drugs to treat alcohol misuse in 2017

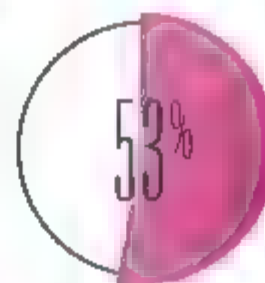


of alcohol-related deaths are due to alcoholic liver disease

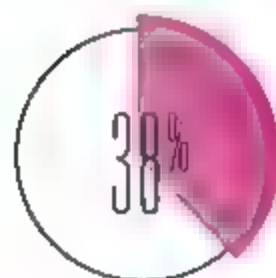
£8-13bn

Total annual cost of alcohol-related crime

Source: Alcohol



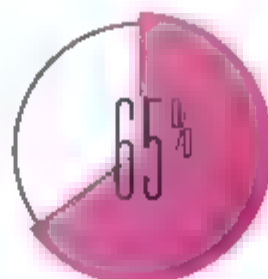
of victims of violent incidents believe the offender is under the influence of alcohol



of young people aged 11-15 have drunk alcohol (2014)

£3.5bn

Annual cost to the NHS of treating alcohol-related illness and injuries



of all alcohol-related deaths are male

60+

Medical conditions are linked to alcohol use, including various cancers and depression

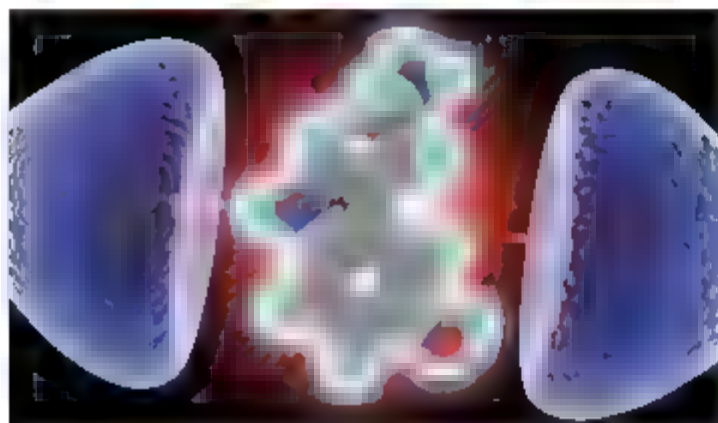




ABOVE The rave scene increased the illegal use of MDMA

FAR LEFT MDMA increases levels of serotonin, seen here between two nerve cells

LEFT MDMA is also known as ecstasy and most often comes in tablet form



It started in medicine. It was useful and we were making some great strides. It then stopped for 30 years but now we're bringing it back into the clinic, where it belongs. Because from a pharmacological perspective, MDMA is a remarkable compound that works across a number of different receptors."

MDMA works because it acts upon serotonin receptors in the brain. It increases the levels of serotonin – the 'happy' neurotransmitter – to create the drug's well-known ecstatic or euphoric effects. At the same time, it activates other receptors to provide a mild psychedelic effect – not enough to make the walls seem like they're melting, in the way that LSD and DMT do, but enough to boost the user's creative thinking and open their mind to new possibilities.

Paradoxically, MDMA also affects the brain's noradrenaline and dopamine receptors, which means it has an amphetamine-like stimulant effect while simultaneously inducing feelings of relaxation – this is why ecstasy users often talk about feeling 'fuzzy' or 'fluffy'. It also boosts the brain's production of oxytocin – the bonding hormone that breastfeeding releases

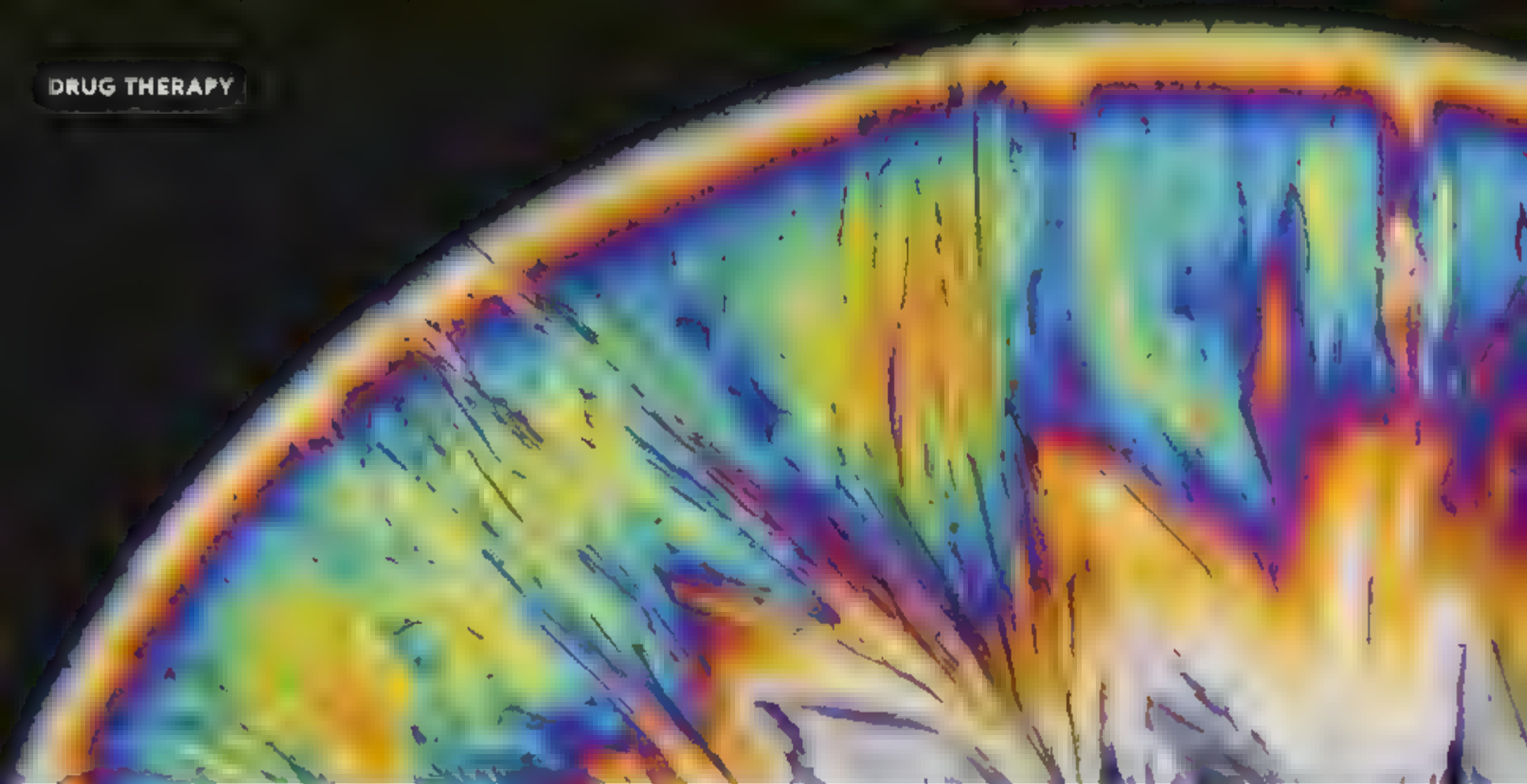
in the brains of new mothers.

#### A SAFE SPACE

Essentially, MDMA mutes the fear response while keeping the other cognitive faculties intact. It's this, says Sessa, that makes the drug such a powerful therapeutic tool. "In some cases, we're working with people who've never experienced a positive mood before," he explains. "They've been living with fear and pain for their entire lives, but now they have this MDMA experience, and they feel good. They feel warm, safe, serene."

"Now a cynic would say, 'But that's a drug-induced experience: it's transient, it's not real.' Which is true, but it's still a valuable experience for someone who's never had peace in their lives. For six hours, they've got peace, and yes it's a transient, drug-induced peace, but that's a useful platform because while they're in that positive mood you can do a lot of good work."

Participants for the Bristol study are recruited from clients of Addaction, a national addiction and recovery service with a base in Weston-super-Mare. They must not be addicted to any other substance. ●



ABOVE MDMA crystals under a cross-polarisation microscope

• (other than caffeine and nicotine) and they must not have taken MDMA in the past six months, or more than 20 times in their lives. There is also a series of tests to weed out anyone who may have other conditions, such as a weak heart or certain psychiatric disorders, that make MDMA use inadvisable.

Once patients have been accepted and have detoxed (either by gradually reducing consumption over several months or after a tapered programme of benzodiazepines over a period of 7-10 days to counter the potentially fatal effects of alcohol withdrawal) they commence their psychotherapy with Sessa and Higbed. The programme involves 10 psychotherapy sessions over eight weeks – only two of which are MDMA-enhanced. There are then follow-up sessions at three, six and nine months.

The MDMA sessions take all day, with patients given a dose of MDMA, followed by a second, smaller dose two hours later. The sessions take place in the Sleep Studies suite at St Michael's Hospital in Bristol, which is specially re-dressed for the occasion with soft lighting, throws on the bed and rugs on the floor to create a less intimidating environment. Participants lie on the bed with the two therapists either side of them and don an eyemask and headphones through which a playlist of ambient music specially curated to reflect the peaks and troughs of the MDMA experience is played. And then the talking starts.

"The patients aren't just lying there in ecstasy, saying 'I love everything'," Sessa is keen to point out. "We're asking them to go to some dark places and to do some very difficult work. But with MDMA, its selective inhibition of the fear response has an extraordinary effect and when we ask about their childhood, they're amazed at their own ability. They say things like, 'My God, I can actually tell you all about it'. The MDMA provides a kind of life jacket that protects you from the fear and allows you to do the psychotherapy. You've

spent 20, 30, 40 years avoiding these memories, but with MDMA you can go there and talk about it."

Alternatively, some patients may not talk at all – and that's okay, says Higbed. "We trust the process and know that they're having an internal experience. That's why the patients stay overnight, and why we have another session the next morning before we send them home, where we talk about their experience and help them to integrate it into their lives."

#### RISK VS REWARD

Eyebrows are inevitably raised whenever the use of illegal drugs is discussed. Some question whether MDMA treatment could lead to a new addiction, while others may ask how safe the whole process is.

Sessa is sanguine on both counts. "The risk of addiction is staggeringly low," he says. Approximately 600,000 people took ecstasy each year between 2000-2015, according to figures from the Crime Survey for England and Wales, "but MDMA dependency is still as rare as hen's teeth," says Sessa. "I've only heard of one case. Ask any psychiatrist if they have any MDMA addicts on their wards, and they'll tell you it's just not on the radar." According to Sessa, there have been some 1,600 MDMA sessions given clinically over the past 10 to 15 years and not one single case of dependence has been reported. Mephedrone, meanwhile, appeared as a recreational drug around 2007, and although experts say more evidence is needed to determine if it can cause addiction, a small-scale survey of users in 2011 suggested 30 per cent of them showed signs of dependence.

"As for safety, no medical intervention is ever totally risk free," says Sessa. "As doctors we don't use abstract terms like 'safe' or 'dangerous'. We ask: 'Is this intervention justified in this particular person at this particular time? Does it come down on the side of



benefits and can we keep risk to a minimum? 'That's the same whether we're sticking on a plaster or removing your bowel. And when you put MDMA through that analysis – here's a patient who's experienced childhood trauma, who has 20 years of alcoholism, who's had all kinds of medication, who's been in and out of hospital, been sectioned, attempted suicide... can we justify a controlled dose of MDMA in a clinical situation? It's an absolute no-brainer. The risk is very, very small compared to the enormous benefits.'

#### THE ROAD AHEAD

Sessa explains that in rare cases you can get a negative reaction, but they do a lot of physiological screening to avoid that. Plus, all patients have blood tests and an ECG, and are screened for certain mental problems. While the MDMA experience is taking place, the patients are monitored and their blood pressure and temperature is recorded every half hour, to minimise risk.

Still, these are early days and Highed says that we are still a long way from treatment. The work being carried out in Bristol involves fewer than 20 patients, and is what's known as an 'open-label, proof of concept, safety and tolerability study'. This means that everyone knows they're receiving MDMA, and the real test is to see if this application of the drug has any negative effects. If none are apparent, then Sessa and Highed hope to get funding for a full-scale, double-blind, placebo-controlled study. And both are hopeful. "When I first got involved with this project, I read about the Mithoefer study from 2010, where Michael and Annie Mithoefer in the US used MDMA-assisted psychotherapy to treat Vietnam War veterans with chronic PTSD," says Highed. "After 12 weeks they were free of symptoms and they maintained that over three, six and nine months. That's pretty much unheard of. Now in our study, we've got two patients coming up to their six-month follow-ups and one coming up to three months, and so far two of them haven't picked up a drink at all, and one's only had a single drink on a couple of occasions. That's already a better success rate than many other programmes."

Longer term, Sessa imagines a future where MDMA therapy will be available on the NHS. "It'll never be a take-home drug. But MDMA is on course to be A-approved by the European Medicines Agency in 2021, and after that you should be able to get this treatment legally, on the NHS, delivered through MDMA therapy centres. And the one we're setting up in Bristol will be the first." 🍄

Russell Deeks is a freelance science and technology writer

## DRUGS FOR GOOD

MDMA isn't the only illegal drug that can be useful in a clinical setting

### LSD

Like MDMA, LSD may have benefits as a tool for therapy. In 2017, a metastudy of LSD research over the past 25 years, published in the journal *Neuropsychopharmacology*, found that LSD increased feelings of openness, trust and suggestibility, dampened the fear response and enhanced emotional empathy. It has proved particularly useful in treating anxiety in terminal patients, with as few as two doses causing a reduction in symptoms.



### Ketamine

Ketamine was developed in the 1960s as an anaesthetic and is still used medically in that context. Recreational use can cause problems with the liver and urinary tract, but the drug can also be beneficial in treating depression, particularly in those who have proved resistant to other treatments. A 2018 study published in the *American Journal Of Psychiatry* found that ketamine delivered as a nasal spray could cause an almost immediate reduction in symptoms.



### Psilocybin

Magic mushrooms have a similar effect on the brain to LSD, so unsurprisingly psilocybin (the active ingredient) can be similarly useful in treating depression and anxiety. A 2017 study at Imperial College London showed marked improvement in symptoms and increased brain activity in patients given the drug.



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# FIZZ, POP, BANG!

Every year at the Royal Institution's Christmas Lectures, an expert designs exciting experiments to educate an audience of children about an important issue in science. Ahead of this year's event, we take a look at 10 objects that have enjoyed a prime spot on the Royal Institution stage.

WORDS: HILLARY GLENNY

**B**ack in 1848, Michael Faraday first gave his famous lecture series 'The Chemical History Of A Candle' at the Royal Institution Christmas Lectures. In doing so, he taught young boys in the audience about the physics and chemistry behind one of the most essential items in their homes.

The principle has stayed the same over the decades, with each year's lecturer tackling contemporary topics in front of

an audience of spellbound schoolkids. Now, 170 years on from discussing the science of candles, speakers have taken on topics like hacking your home, how to survive in space, and whether or not you could live forever.

While scientific knowledge has continued to improve, the presenters of the Christmas Lectures have consistently used over-the-top props and often nerve-racking experiments to get their young audience excited about the world of science. These 10 items mark some of the most significant moments in the history of the Christmas Lectures.





### ◀ 1. MICHAEL FARADAY'S BURN MARKS

Michael Faraday launched the Christmas Lectures in 1825, and although he wasn't the first presenter (John Millington hosted the debut lecture), he went on to give a record 19 lectures. His most well-known series, the

Chemical History Of A Candle, was written up and is one of the best-selling science books of all time.

The Royal Institution still houses his meticulous notes from the lecture series, complete with a large burn mark across a few of the pages. Although no one knows exactly how it got there, Faraday's lectures included experiments where he set fire to saucers filled with brandy, so perhaps it's no surprise that some of his notes were scorched in the process!



### ▲ 2. ALEXANDER OLIVER RANKINE'S HOMEMADE SNOW

Alexander Oliver Rankine, a British physicist, enthralled his audience by creating snow in the Royal Institution lecture theatre in 1932. He plunged a red-hot poker into a solid fuel called 'meta fuel', evaporating it and it then re-condensing it into fluffy white particles in the air. In reality, this 'snow' had more in common with ash, but the effect worked.

Rankine also demonstrated to his audience that there was enough water vapour in the theatre for someone to 'wash comfortably': he used similar methods to develop a technology called FIDO, which was used to clear runways of fog during WWII.

### ◀ 3. MAX THE LION CUB

Julian Huxley, secretary of the London Zoological Society, gave his 1937 lecture on rare animals and the disappearance of wildlife. An active campaigner for endangered species, he showed his young audience a film of baby seals being clubbed in the Arctic, and brought in live animals from London Zoo, including snakes, crocodiles and a red kite.

But the audience's favourite animal was Max, a lion cub. Huxley brought him in to show the audience that lion cubs have spots on their fur that fade as they reach adulthood.



In 1968, inspired by Gulliver's fictional travels, physicist Philip Morrison lectured on size and perception. He used a 12ft (3.6m) ruler and a giant pencil to measure a huge penny, to recreate how one of the inhabitants of Lilliput would've viewed Gulliver's English pennies.

The enormous pencil and ruler recently got another airing when they were dug out of the archives by Mark Modownik, a materials science who gave the Christmas Lectures in 2010



In 1973, David Attenborough brought out Tammy, an uncooperative ring-tailed lemur, to illustrate a point in his lecture on the language of animals. Ring-tailed lemurs have glands on the insides of their arms, from which they secrete a scent. When threatened, a ring-tailed lemur will rub their tail on the glands, then wave it around to create a curtain of smell. It's a behaviour that help lemurs intimidate others, avoiding dangerous and tiring physical fights.

Unfortunately, Tammy wasn't keen on showing his glands to the audience, but the kids were still charmed by the little lemur as he clung to Attenborough's chest and gobbled up grapes.



## RICHARD CANNON'S CLASSICAL

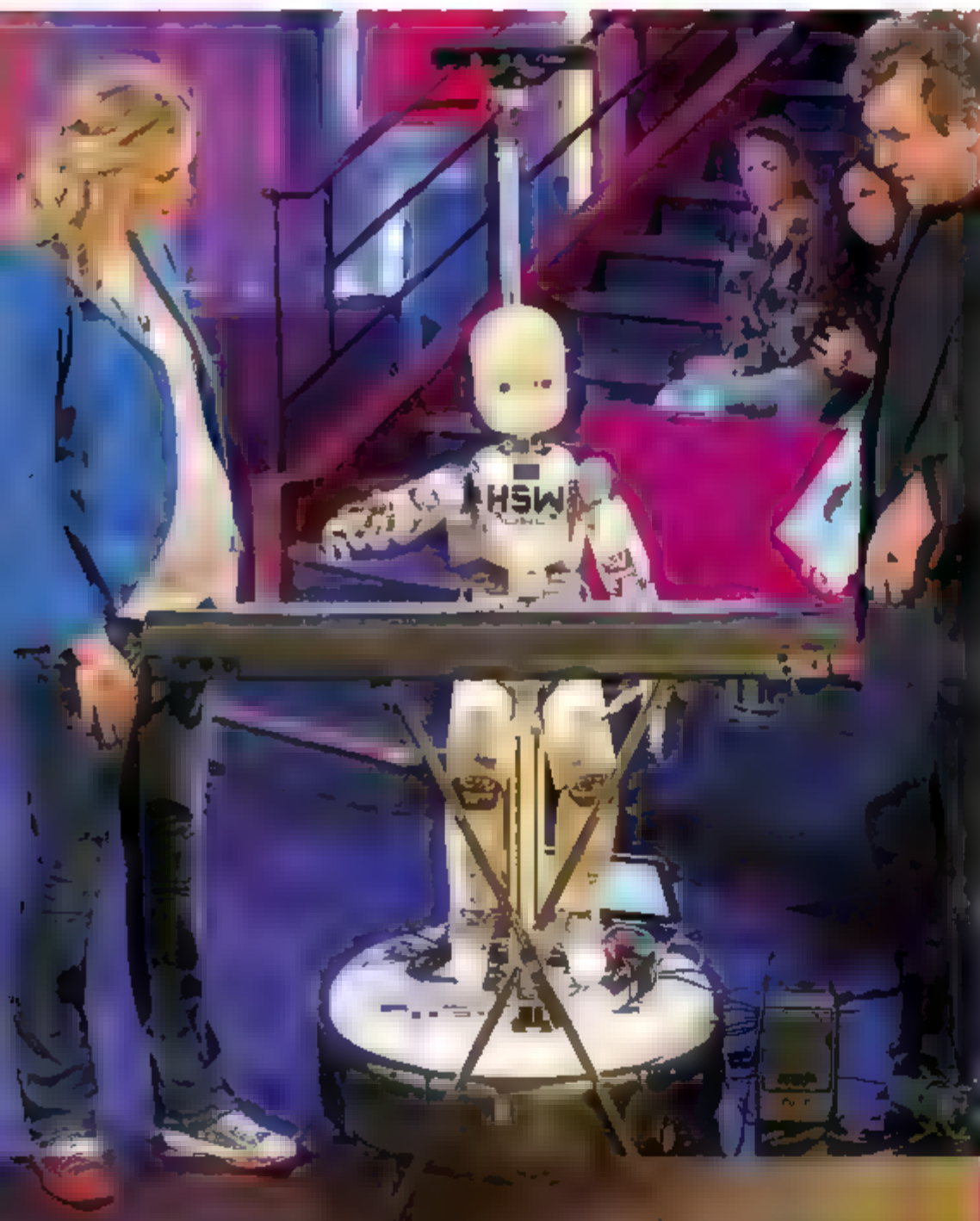
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### 7. KEVIN FONG'S TOWEL

In his 2015 lecture, Kevin Fong discussed how to survive in space, cutting back and forth between the Royal Institution and the International Space Station (ISS), where British astronaut Tim Peake had just taken up residence.

Fong discussed how astronauts stop their bones and muscles from wasting away when they're living in zero-gravity, and also explained how to cope with a medical emergency in space. Fong was able to send a practical present up to the ISS — this nifty hand towel, to remind Peake of the golden rule when facing a medical emergency: don't panic.



### 8. H5W: THE KEYBOARD-PLAYING ROBOT

Danielle George created an entire robot orchestra for her 2014 Christmas Lecture, and one of its most impressive members was H5W, a piano-playing robot created by Pompeu Fabra University in Barcelona. The robot was able to play specific notes when asked, and tapped out the start of *Twinkle, Twinkle, Little Star*. The robot claimed that the task was quite simple.

During the orchestra's performance, H5W played the theremin, an instrument that consists of two metal antennas. The antennas sense the position of a musician's hands, and the musician then plays the theremin by moving their hands around. Playing a theremin involves constantly listening to the sounds you're producing and adjusting on the fly. H5W mastered the task with ease, making it one of the stars of an orchestra that also included an old dot-matrix printer, a drone, and pipes made from shaving

### 9. THE WORLD'S LARGEST LEMON BATTERY

In his 2016 lecture, materials chemist Saiful Islam demonstrated that you can create voltage with just a lemon, a copper nail, a magnesium strip and a few wires. He then took 1,013 lemons, cut them all in half, connected them together, and created the world's largest lemon battery. It was so large that it had to be filmed in the

lecture theatre.

With adjudicators looking on, Islam set a Guinness World Record for the highest voltage produced by a fruit battery, clocking in at 1275.4V.



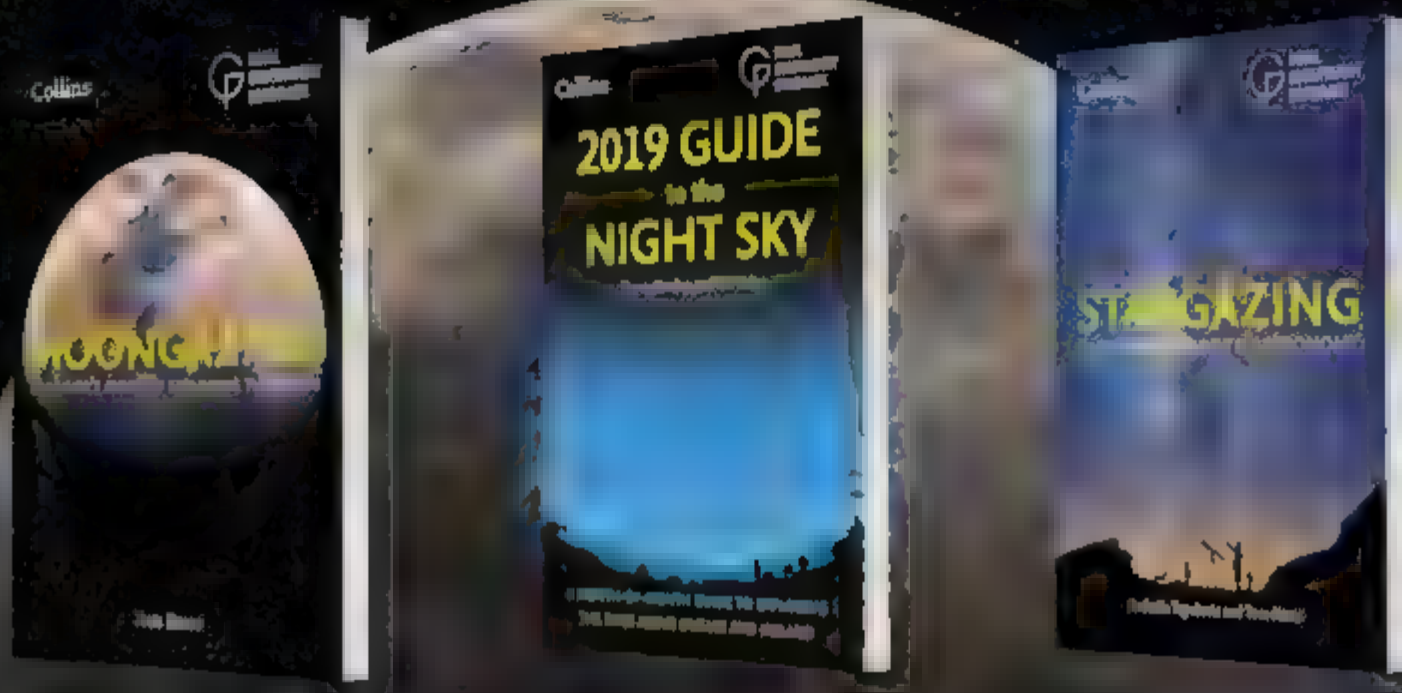
### 10. SOPHIE SCOTT'S SWEET CANNON

To illustrate how powerful scent messages can be as a means of communication, in 2017 neuroscientist Sophie Scott loaded up a cannon with some pungent smells and puffed huge, aromatic smoke rings at the crowd. Luckily for them the first smelt a little like candy floss. She then loaded the cannon with a synthesised version of the molecules in poo, and shot those smoke rings at some unsuspecting audience members, who took it quite well. Her point was that smells contain important information, and that while a candy floss aroma tells us something might be edible, a poo smell lets us know that an object might be contaminated, and it'd be best not to consume it.

Scott also gave us a glimpse into direct, silent communication via brain waves, suggesting that's how we could exchange ideas in the future. So what could we be learning about in the upcoming decades of Christmas Lectures? The possibilities are unimaginable. 



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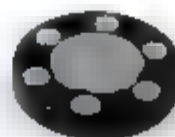
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First you notice that it is levitating, then you notice it is spinning using just the power from the sunlight. Ultra-strong neodymium magnets keep it levitating, while more magnets and copper coils and solar panels keep it rotating.



A very interesting simple and fun toy. When the lower portion of the glass sculpture is held, the liquid rushes into the upper section, and appears to boil furiously. Then hold the top section and liquid returns to the bottom.



Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you can create are mesmerizing.

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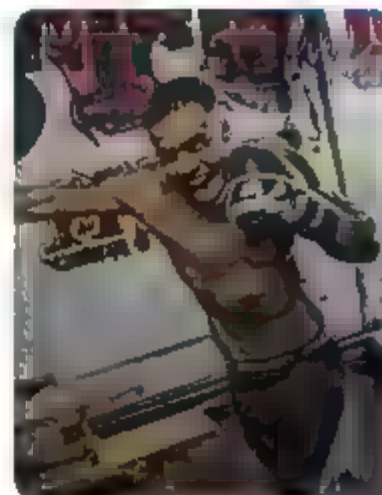
🌐 [dnafit.com/xmas](http://dnafit.com/xmas)

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## The Sharpham Trust

### Mental Wellbeing

The Sharpham Trust is a meditation and nature charity situated on a beautiful estate beside the River Dart in south Devon. The Trust runs mindfulness retreats and courses with an emphasis on the benefits of reconnecting with nature.



🌐 [sharphamtrust.org/](http://sharphamtrust.org/)

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# YOUR QUESTIONS ANSWERED

CHRISTMAS 2018

EDITED BY JAMES LLOYD



## Where do birds sleep?

FRED JOHNSON, BRADFIELD

Birds usually practise 'unihemispheric' sleep, meaning that they rest one half of their brain at a time, keeping them semi-aware. But they're still at high risk of predation. Strategies to minimise the chances of being eaten include resting on water or on predator-free islands, roosting in dense shrubs or high up in trees, or hiding in cavities such as chimneys. Birds will often opt for safety in numbers, grouping together in hundreds or even thousands. **CC**



## If an AI became sentient, would it gain human (or equivalent) rights?

JAMES TURNER, SOMERSET

We call a creature sentient if it can perceive, reason and think, and also if it might suffer or feel pain. Scientists suggest that all mammals, birds and cephalopods and possibly fish too, may be considered sentient. However we do not grant rights to most creatures, so a sentient AI may not gain any rights at all. AIs also have another big problem: they lie to us. Today's AIs all pretend to understand us and have emotions. If you ask Siri if it is happy, it may say it is overjoyed, but the words are hollow – it feels nothing. This makes it even harder for the AIs of the future. How do we know if the AI is sentient, or if it's just pretending? ➤

## Is it bad for us to eat too many alkaline foods?

LOUIE BAILLIE, ST ALBAN'S

Proponents of 'alkaline diets' claim that too much acid in the blood can cause a range of health issues, from osteoporosis to cancer. They advocate filling up on alkaline foods (those with a pH higher than water), but the body's system for regulating blood pH is actually unaffected by diet. As luck would have it, though, alkaline foods *do* tend to be healthy – they include fruits, beans, nuts and vegetables. So it's not bad to eat 'too many' of them. On the other hand, cutting down on many acidic foods, such as refined sugars, coffee and alcohol, won't do any harm. ➤



## WHAT CONNECTS...

### CHRISTMAS AND THE DEATH OF THE UNIVERSE?

# 1.



When you pull the Christmas tree lights from the box of decorations this year, don't be surprised if they're in a hopeless tangle. It's actually a law of the Universe.

# 2.

A 2007 study at the University of Chicago found that strings longer than 45cm long will spontaneously tie themselves into knots if they are shaken randomly in a box.



# 3.

This is a consequence of entropy, which is a measure of the disorder of a system. The second law of thermodynamics states that the entropy of the Universe is always increasing – in other words, things are more likely to tangle than disentangle.



# 4.

Once the Universe reaches maximum entropy (in roughly  $10^{100}$  years) no chemical or physical interactions will be possible. This 'heat death' is one of the possible ultimate fates of the Universe.





## IN NUMBERS

10,000

### Why is rice such a food-poisoning culprit?

JERRY PORTER, SWANSEA

Dormant bacteria (spores) called *Bacillus cereus* can be found lurking in uncooked rice. The bacteria transfer to the rice from paddy field soil and their spores last for years, even surviving cooking. But when cooked rice is left at room temperature, the warm, damp conditions awaken the bacteria and they produce toxins that can cause vomiting and diarrhoea. The trick is to serve and eat rice as soon as it has been cooked. If you do need to keep it for a later sitting, cool it as quickly as possible and transfer straight to the fridge.



### Why do I lose my hearing when I yawn?

ADR AN SINCLAIR, AUSTIN

This is due to a muscle in your middle ear called the tensor tympani which is attached to the small hammer bone that transmits sound from the eardrum. The muscle automatically contracts to reduce our hearing sensitivity in response to a sudden loud sound like thunder, and it also contracts as we chew, so we aren't deafened by the sound of our own jaw muscles. Yawning also involves jaw movements that trigger the tensor tympani, though, so a side effect is that we get deafer during a yawn. **tv**

## THE THOUGHT EXPERIMENT

# WHAT WOULD HAPPEN IF... WE CELEBRATED CHRISTMAS EVERY DAY?



### 1. OBESITY

In the UK and Ireland, we eat an average of 3,289 calories each on Christmas Day. That's more than anywhere else in Europe. If you ate this much every day, you would put on 37kg (almost six stone) in a year! The fact that most of us also spend Christmas Day immobile on the sofa could make it even worse.



### 2. INSURANCE

Burglary rates tend to spike on Christmas Eve as thieves target homes full of presents. But on Christmas Day itself, most of us are indoors all day and burglary rates fall. That doesn't mean you're safe, though. Christmas is the worst day of the year for house fires, thanks to all the candles and flambéed Christmas puds.



### 3. POWER

The extra power needed to roast a turkey for five hours costs the country an extra £15m collectively. Factor in the cost of running the Christmas-tree lights all day and you get a national electricity bill that's £18.75m higher for the day – nearly £7bn over a full year of Christmases.



### 4. ECONOMY

More than 97 per cent of the UK workforce has the day off on Christmas Day. Extended year-round, this would plunge the economy into crisis. The new economic superpowers would be those countries that don't celebrate Christmas. These include China, Iraq, Iran, Morocco, Saudi Arabia, North Korea and – ironically – Turkey.

## Could science help Santa deliver all his presents?

RUBY BRENT ESSEX



Most attempts to solve this problem assume that Santa must zig-zag around the world in just 24 hours (or 32 if he exploits international time zones). Inevitably this means Santa would need some physics-defying technology, such as a faster-than-light warp drive for his sleigh. But really, distance isn't the main problem, it's the number of deliveries. Estimates vary regarding the number of households worldwide that celebrate Christmas, but Santa probably delivers to between 200 and 700 million children, which means at least 1,700 deliveries every second. The only way he can pull this off is by delivering

multiple presents at a time. If Santa operates from a polar orbit in space, rather than criss-crossing the sky, he can easily fly over the entire planet in 24 hours as it rotates beneath him and he wouldn't even need to break the laws of physics. The presents can be delivered in batches, using repurposed 'Multiple Independently targetable Re-entry Vehicle' (MIRV) missiles left over from the Cold War. As each warhead closes in on a neighbourhood, it splits open to release hundreds of quadcopter drones that simultaneously fly off to different houses and deliver a single present each. **W**

## Why is destruction so satisfying?

ROGER CAI CHICAGO

Feeling in control is a basic human need and one theory posits that deliberately destroying things is incredibly satisfying because it makes us feel powerful. Anecdotal evidence from visitors to 'anger rooms' indicates that there's also a cathartic element, especially when we've been suppressing frustration in our everyday lives. Many people also get a thrill from watching things being smashed to pieces. In this case, curiosity, awe and aesthetics are at play as we wonder how long the doomed object will survive and how it will look when it explodes. **Q**







## How old is the 'Man in the Moon'?

ADAM PERKINS, EXMOUTH

The face-like pattern of light and dark on the full Moon is a classic example of pareidolia, in which our minds conjure up familiar objects from random shapes. In the case of the Moon, those shapes take the form of the so-called 'maria' (from the Latin for 'seas'), such as Mare Tranquillitatis – the Sea of Tranquility, where Apollo 11 landed almost 50 years ago. In reality, these 'seas' are vast plains of relatively dark lava that spewed out of the Moon's interior when it was still molten. The sheer antiquity of the maria was one of the most startling discoveries to emerge from studies of the rock samples brought back by the Apollo missions, which showed that the maria are typically around 3.5 billion years old. In other words, the Man in the Moon we see today has looked down on the Earth since long before complex animals emerged around 500 million years ago. **RM**

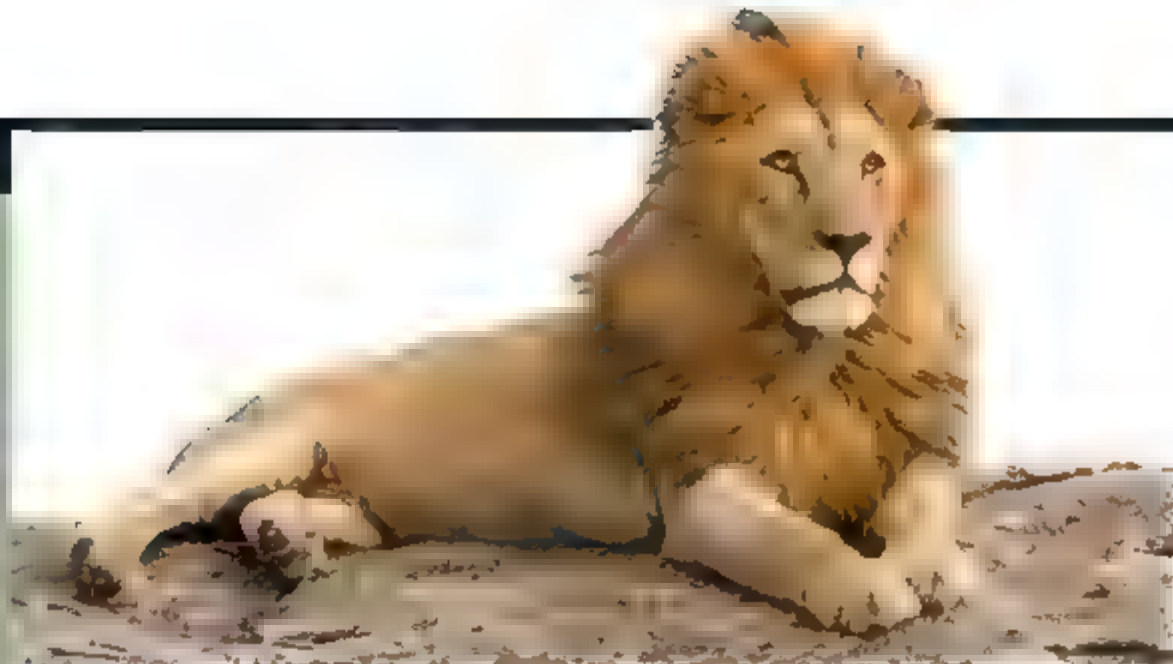
## Does flossing your teeth really make a difference?

IAN STYLES, LONDON



For years, dentists have told us to floss as well as brush our teeth. And it seems to make sense: less gunk between our teeth should lead to less decay. Yet surprisingly, there's little evidence it's true, as it's never been put to the test in a large clinical trial. Some small studies have found that flossing helps combat gum disease, but there's no compelling evidence that it also stops tooth decay. So does that mean it's pointless? Not at all. First, gum disease is a major cause of tooth loss. And second, just because researchers haven't done a proper study, it doesn't mean flossing can't also prevent tooth decay: the absence of evidence doesn't mean there's no effect. **RM**

## WHO REALLY DISCOVERED?



## Why do lions have manes?

BY JESSICA K. HALE

At the onset of sexual maturity, male lions will start to grow thick manes around their head, neck and underbelly. The hormone testosterone is responsible for this process — interestingly, neutered males usually lose their manes entirely. Studies have shown that females are attracted to bigger, darker manes, so it

seems that manes are a signal of sexual fitness. Lions often live in open savannah habitats, so it's particularly beneficial to have evolved a visual method of communicating strength and status. Manes also provide added protection from injury when males fight with one other. **Q**

## What is the smallest known star in the Universe?

BY JESSICA K. HALE

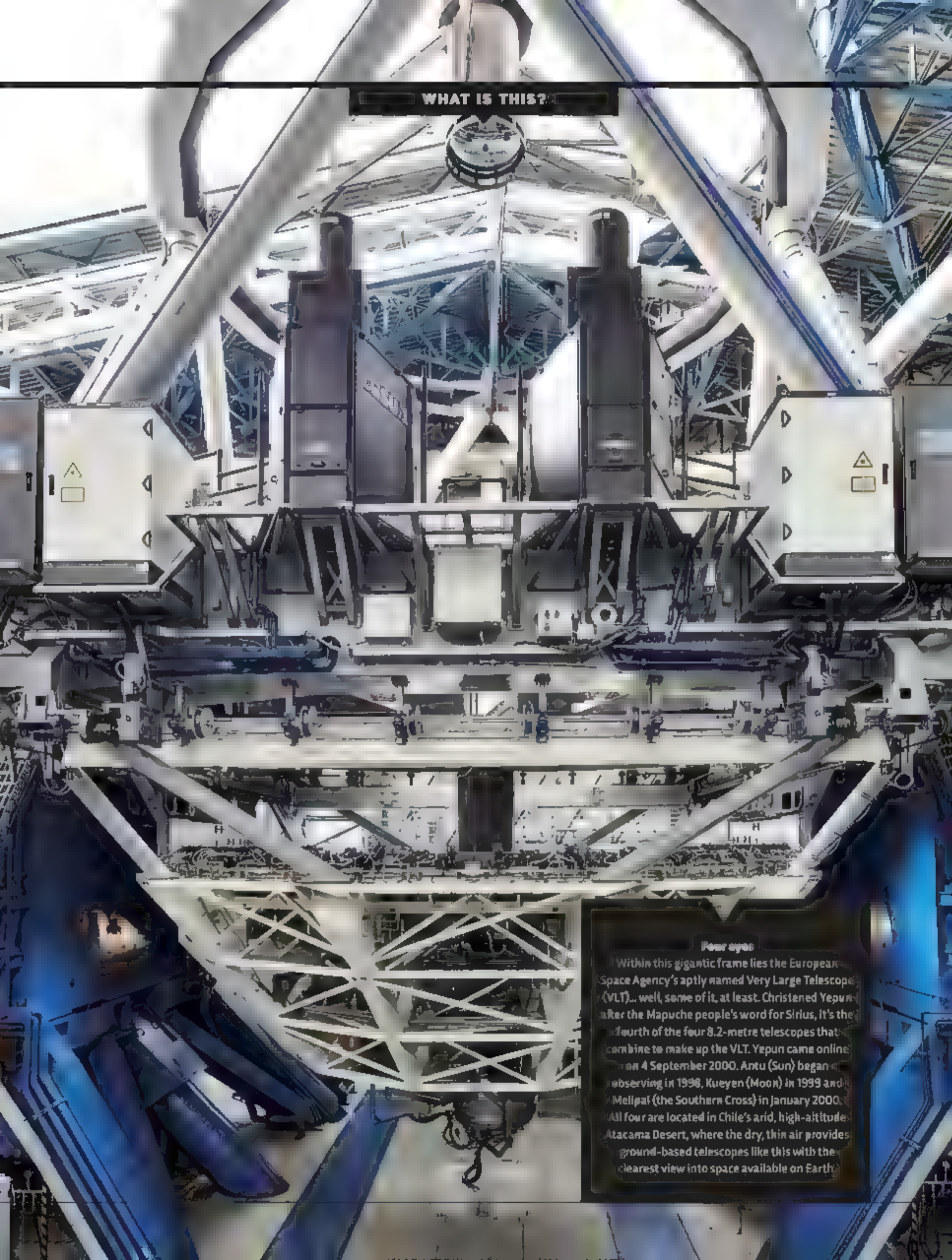


In 2017, an international team of astronomers announced the discovery of a so-called red dwarf star that's so small it barely functions as a star. Code-named EBLM J0555-57Ab and lying some 600 light years away, it's similar in size to the planet Saturn. It has just enough mass to maintain the conditions needed to fuse together nuclei of hydrogen — the power source of stars like the Sun. Any smaller, and it would have become a brown dwarf — a 'failed star'. **AM**



Where am I? A network of orbiting atomic clocks lets GPS answer that question for you





WHAT IS THIS?

#### Four eyes

Within this gigantic frame lies the European Space Agency's aptly named Very Large Telescope (VLT)... well, some of it, at least. Christened Yepun (after the Mapuche people's word for Sirius, it's the fourth of the four 8.2-metre telescopes that combine to make up the VLT. Yepun came online on 4 September 2000. Antu (Sun) began observing in 1998, Kueyen (Moon) in 1999 and Melipal (the Southern Cross) in January 2000. All four are located in Chile's arid, high-altitude Atacama Desert, where the dry, thin air provides ground-based telescopes like this with the clearest view into space available on Earth.

## CAN WE MAKE AN ARTIFICIAL WOMB?

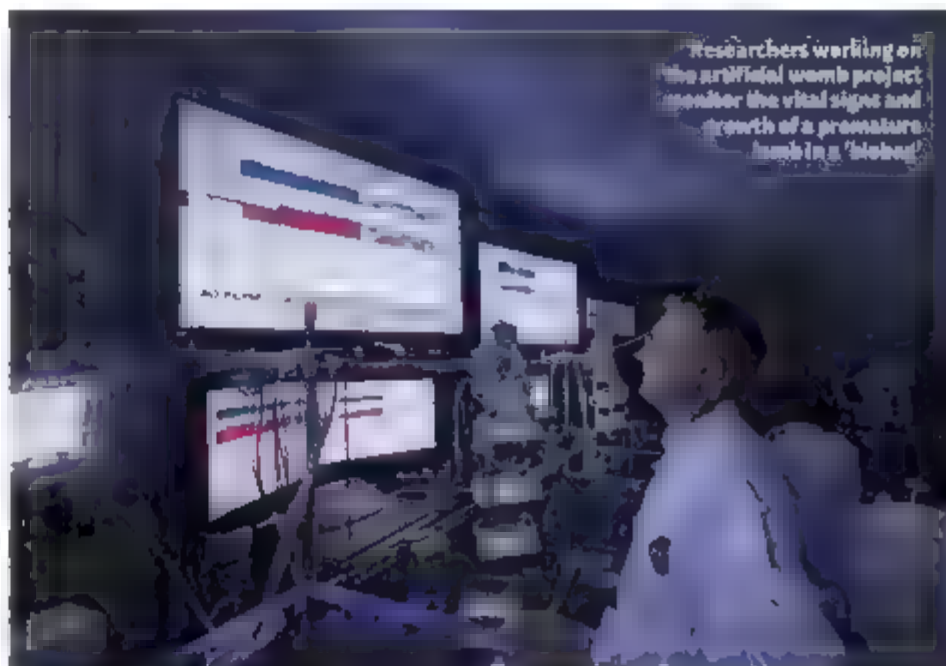
We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at [www.bbcworldservice.com/crowdscience](http://www.bbcworldservice.com/crowdscience)

### Why might we need artificial wombs?

Researchers hope that artificial wombs will increase the survival chances of extremely premature babies, allowing the babies to develop as if they're still inside the mother. In 2017, paediatric surgeons at the Children's Hospital of Philadelphia in the US revealed a new technique that involves suspending the foetus in a 'biobag' full of synthesised amniotic fluid. They've so far tested the device on premature lambs, attaching the animal's umbilical cord to a gas exchange machine outside the bag that keeps the blood topped up with oxygen and nutrients. Some of the lambs were kept alive up to birth weight, so if the team can make this technology safer, they may be able to adapt it to save human babies.

### What does a baby get from the mother?

Millions of years of evolution have made mammalian pregnancy an extraordinarily complex and well-honed system. The mother and foetus are intimately connected via the placenta – an organ that is grown by the foetus into the mother's womb lining. Oxygen, nutrients and a cocktail of hormones pass from the mother into the baby via the placenta, stimulating and maintaining the pregnancy as the baby develops. Meanwhile, the baby passes carbon dioxide and other waste products back into the mother's bloodstream. The mother's body heat is also important to the baby's development. An artificial womb would need to replicate all of this.



### What are the biggest barriers to artificial wombs?

Probably the least understood stage of pregnancy – and one of the most delicate – is around 10 days after fertilisation, when the developing egg implants into the uterus and starts to grow. Researchers are now experimenting with maintaining uterus cells outside of the body, which in future could be supported in an artificial womb and provide a place for the embryo to implant. This uterus tissue would need to have its own blood supply – something that's not yet been achieved. Scientists believe that tackling this issue would be a major step towards artificial wombs.



Rory Galloway is the producer of *Can We Make An Artificial Womb?* – an episode of *CrowdScience* that can be streamed at [bbcworldservice.com/crowdscience](http://bbcworldservice.com/crowdscience)







## Does blushing have any evolutionary purpose?

SOPHIE CLAY, MANCHESTER

Charles Darwin was intrigued by blushing, calling it "the most peculiar and most human of all expressions", but it would be more than 125 years before we had any hard data on what evolutionary function blushing might have. We now know that when people blush after a transgression or mishap, their state of shame and embarrassment is considered more intense by onlookers, and as a consequence they are viewed more favourably – perhaps because it signals their realisation and regret that they have transgressed. For instance, in one study, Dutch psychologists found that cheaters in a financial game who subsequently blushed were soon trusted again. So blushing seems to have evolved as a form of non-verbal communication, helping us to bond with others by showing our concern for social rules. **Q**

## Can men and women evolve separately?

LISA MILNE (AGE 14), OXFORD



They have evolved separately, which is why the two sexes are physically different. Evolution has favoured men who have lots of children, so their biological contribution to reproduction is just a few millilitres of cheaply produced sperm. Women, on the other hand, need to supply literally all the energy and nutrients required to build a baby from scratch and feed it, so they've evolved a uterus, placenta and milk-producing breasts. However, there is a limit to how far the sexes can diverge. Men and women only differ by one chromosome – the Y chromosome – and all the physical and hormonal differences between the sexes ultimately have to fit into that one chromosome. **W**

## QUESTION OF THE MONTH

### What is the time resolution of our senses?

JILLIA NELSON (AGE 10), HAMPSHIRE

When you watch a film, the cinema projects a series of still frames one after the other, but you perceive it as continuous motion because each frame is only shown for about 40 milliseconds. In fact, under ideal conditions we can spot a flicker in a light even if it lasts for just 25 milliseconds. Our other senses react at different speeds, though. Hearing is much faster, with a time resolution of just three milliseconds, but touch can only manage 50 milliseconds. Smell and taste are the slowest and can take more than a second to react to a new sensation. **W**

### WINNER!

Lika wins a Google Home Mini. The most affordable and compact of Google's Assistant-enabled speakers, the Home Mini (£49, [mobiles.co.uk](http://mobiles.co.uk)) can be used on its own or alongside other Google Home devices, and lets you do quizzes, play music and games, and search for information – simply by talking to it.



## NEXT ISSUE:

How tall is the Universe?

Why do kids pick their noses?

# OUT THERE

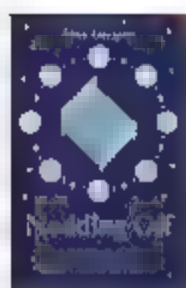
HOW WE'RE FEEDING OUR MINDS THIS CHRISTMAS

CHRISTMAS 2018

EDITED BY HELEN GLENNY

## 01 CURL UP WITH A BOOK

Science writers took on a tonne of fascinating topics in 2018, infusing their books with facts, comedy, human narratives and practical tips. Here are 12 of our favourites.



**NODDING OFF**  
ALICE GREGORY  
£12.99 (Doubtful Utility)

After two decades as a prominent sleep researcher, Prof Alice Gregory is well placed to teach us how to sleep better. In *Nodding Off*, she explains the science of sleep and what happens if we don't get enough of it. She also offers important tips on how to improve our shut-eye, to help us feel better in our waking hours.



**HOW TO INVENT EVERYTHING**  
RYAN NORTH  
£12.99 (Barnes & Noble)

Picture this: you've gone back in time for a casual gander at what cavemen were like, or to have a go at taming a dinosaur, but your time machine broke. And you can't fix it. But don't stress, you've got Ryan North's informative manual on how to rebuild civilisation from scratch. Get started with inventing language, and then over 400 pages build your way up to modern computers.



**NOTES ON A NERVOUS PLANET**  
MATT HAIG  
£12.99 (Corgi)

After experiencing years of anxiety and panic attacks, Matt Haig began to look for the links between how he was feeling and what was going on around him. *Notes On A Nervous Planet* is Haig's look into how to feel happy on a fast and nervous planet, and tells us how we can lead happier, healthier and saner lives.



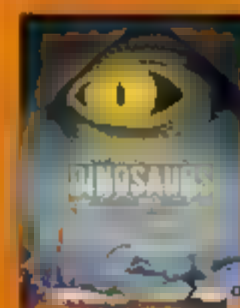
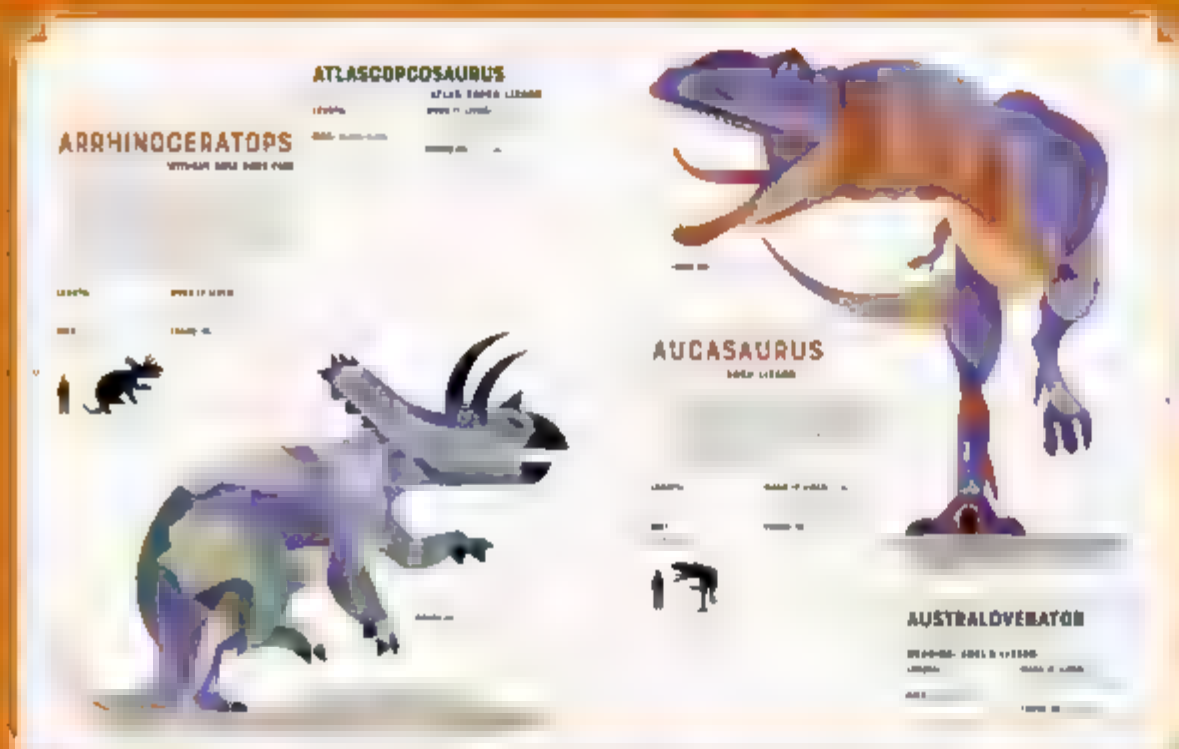
**THE HAPPY BRAIN**  
DEAN BURNETT  
£12.99 (Corgi)

In our constant quest for happiness, we change jobs, pursue relationships, watch stand-up comedy and take up hobbies, among many, many other things. Neuroscientist Dean Burnett combines cutting-edge research and views from all kinds of experts to explain where happiness comes from, and why we need it so much.

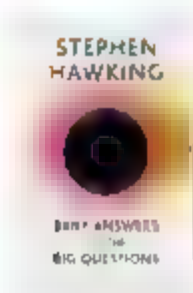


**TOTALLY RANDOM. WHY**  
DEAN BURNETT  
£12.99 (Corgi)





**DICTIONARY OF DINOSAURS**  
MATTHEW G. BARON



**BRIEF ANSWERS TO THE BIG QUESTIONS**  
STEPHEN HAWKING  
EDITED BY LEON MURRAY

Published posthumously, Stephen Hawking's last book tackles some of the Universe's biggest questions. Is time travel possible? Is there other intelligent life in the Universe? How do we shape the future? And unlike *A Brief History Of Time*, this one is actually intelligible to the average armchair reader.



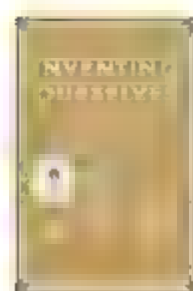
**ENDURE**  
ALEX HUTCHINSON  
£9.99 HARVARD UNIVERSITY PRESS

The capacity to endure underlies most great athletic performances, but what limits endurance? Against the backdrop of some of the world's best athletes trying to break the two-hour marathon mark, Alex Hutchinson explores new science around what defines our limits: is it our bodies, food, or pain? Or is it all in our heads?



**APOLLO**  
MATT FITCH, CHRIS BAKER, MIKE COLLINS  
£14.99 ZAG/RO

*Apollo* tells the suspense-filled story of the first Moon landing in graphic novel form. It's well-researched and includes rich historical detail, tracking not only the mission itself, but the political tension around the programme and the nerve-racking experience shared by the crew's families.



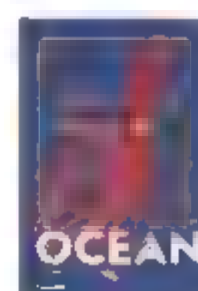
**INVENTING OURSELVES: THE SECRET LIFE OF THE TEENAGE BRAIN**  
SARAH JAYNE BLAKEMORE  
£20 TRAN-WOR/D

Adolescence is a crazy time: there's a need for intense friendships and extreme risk-taking, and it's also when many mental illnesses begin to develop. Neuroscientist Sarah Jayne Blakemore draws on cutting-edge research to explain what's happening in the brains of teenagers, and what it can tell us about how we've all developed.



**THE SCIENCE OF SIN**  
JACK LEWIS  
£5.99 BLOOMSBURY'S CMA

We all sin to some extent, whether that's eating more cake than we know is good for us, or carrying out more serious illicit acts. In *The Science Of Sin*, neurobiologist Jack Lewis talks us through why we do bad things, illuminates the neural battles between temptation and restraint, and helps us understand why we do the things we shouldn't.



**OCEAN**  
HELENE DRUVERT  
EMMANUELLE GRUNDMANN  
£19.95 THAMES & HUDSON

*Ocean* by Hélène Druvert and Emmanuelle Grundmann explains the most fascinating facets of the sea, including waves, coral reefs and the food chain. With captivating fold-out infographics and stunning laser-cut illustrations, it's a beautiful, interactive tome that'll help both kids and adults appreciate our oceans.



02

## PICTURE THIS

As well as being spectacular to look at, these photography books delve into the science behind their subjects



**WILDLIFE PHOTOGRAPHER  
OF THE YEAR: PORTFOLIO 28**  
£75 The Natural History Museum

The Natural History Museum's annual Wildlife Photographer of the Year competition always delivers beautiful wildlife images, like this 'forest within a forest' (above) photographed by Antonio Fernandez. Portfolio 28 features the best of 2018's competition

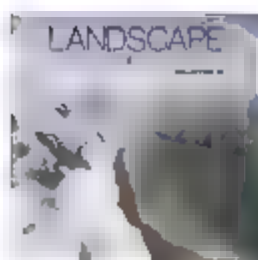


**INFINITE WONDER:  
AN ASTRONAUT'S  
PHOTOGRAPHS FROM  
A YEAR IN SPACE**  
SCOTT KELLY  
£29, DOUBLEDAY

Astronaut Scott Kelly had a year that photographers would envy. He circled the Earth 5,400 times, witnessing 16,944 sunrises and sunsets – about 16 per day. From the International Space Station, he viewed our planet in a unique way, and shares his incredible photos with us in *Infinite Wonder*.







**LANDSCAPE PHOTOGRAPHER  
OF THE YEAR: COLLECTION 12**

£25 AA PUBLISHING

Photographer Dave Fieldhouse captured this nightscape (right) of Battersea Power Station, where feverish activity is turning the architectural icon into a development of bars, restaurants and apartments. You can see this photo, and many more, in the latest edition of *Landscape Photographer Of The Year*



**WONDERS: SPECTACULAR MOMENTS  
IN NATURE PHOTOGRAPHY**

RHONDA DELBSTEIN  
£16 CHRIS LITTLEWOOD

*Wonders* features the award winning images from the BigPicture Natural World Photography competition, like this picture of the Dubai desert by Mark Seabury (left). Along with stunning photos, the book explains the scientific phenomena and photography behind each shot

# 03 TUNE IN

Get through a few science podcasts and radio shows on the long drive to your family this Christmas. Here are five of our favourites from this year



## MORE OR LESS: BEHIND THE STATS SHOULD WE HAVE SMALLER FAMILIES TO SAVE THE PLANET?

[bit.ly/smaller\\_families](http://bit.ly/smaller_families)

Researcher Seth Wynes set out to explore what we could do to prevent climate change, and found that going carless saves 2.4 tonnes of CO<sub>2</sub> equivalent emissions per person per year, while not having children saves 58 tonnes per person a year. Host Tim Harford and researcher Lucy Proctor explore this research



## NATURE PODCAST BUILDING EARLY EMBRYOS, THE FEAR RESPONSE IN MICE, AND ANCIENT RHINO REMAINS

[bit.ly/embryos\\_mice](http://bit.ly/embryos_mice)

Early embryos, called blastocysts, are important in human and animal development studies, but they're terribly hard for scientists to harvest from lab animals. Podcast hosts Adam Levy and Benjamin Thompson talk to researcher Nicolas Rivron about how he's tackling that problem by creating early embryos instead. They also discuss fear in mice, and what ancient rhino remains can tell us about hominin migration

RADIO  
4



## THE GENIUS OF ACCIDENTS

[bit.ly/genius\\_accidents](http://bit.ly/genius_accidents)

Adam Hart examines the most productive accidents in scientific history, including the engine medication that gave us Viagra and the glue experiments that led to Post-it notes.



## SCIENCE FOCUS PODCAST WHAT IT'S REALLY LIKE TO DIE

[bit.ly/palliative\\_care\\_mannix](http://bit.ly/palliative_care_mannix)

In this month's cover feature, one of our experts is Dr Kathryn Mannix, who writes about her experiences treating patients in the final weeks, days and moments of their lives. Here, you can listen to our podcast with her, as she lets us know that the process of dying can be more peaceful and gentle than we're often led to believe.

FREAKONOMICS  
RADIO

## FREAKONOMICS RADIO HOW TO OPTIMIZE YOUR APOLOGY

[bit.ly/opt\\_mise\\_apology](http://bit.ly/opt_mise_apology)

Among others, host Stephen Dubner talks to John List, who was once the chief economist at Uber. After receiving a bad ride (where the driver accidentally drove him back to his original destination) and not receiving an apology, John investigated what would happen if Uber were to apologise after bad rides, and found out how those apologies could be made most effective.



# 04 WATCH OUT

Relax in front of these fascinating documentaries, biopics and sci-fi blockbusters

## DYNASTIES

AVAILABLE ON BBC PLAYER

The new David Attenborough-narrated landmark BBC series follows the power players in five different animal communities: chimpanzees, emperor penguins, lions, tigers and painted wolves. It asks who's in charge, what got them there, and who's lurking in the shadows ready to topple them?



## FIRST MAN

IN CINEMA NOW

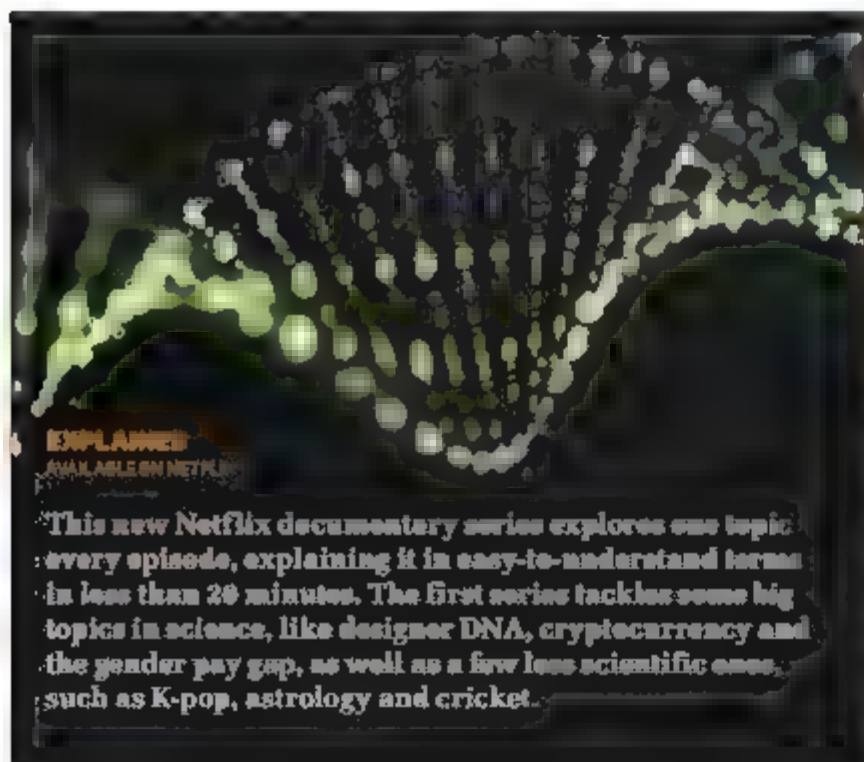
*First Man* documents Neil Armstrong's journey to become the first man to set foot on the Moon. Tracking his career and personal life from 1961 to that famed quest in 1969, it explores the mission's costs to the country, Armstrong's family and Armstrong himself.



## READY PLAYER ONE

AVAILABLE ON KODAK BUDGET (PLAY IT NEARLY VIDE)

It's 2045, and people can escape their uncomfortable reality in the OASIS, a huge virtual world where the only limits are your own imagination. But when the creator of OASIS dies, he leaves his fortune and control of the OASIS to whoever can complete his challenge. And an unlikely hero emerges...



## EXPLAINED

AVAILABLE ON NETFLIX

This new Netflix documentary series explores one topic every episode, explaining it in easy-to-understand terms in less than 20 minutes. The first series tackles some big topics in science, like designer DNA, cryptocurrency and the gender pay gap, as well as a few less scientific ones, such as K-pop, astrology and cricket.



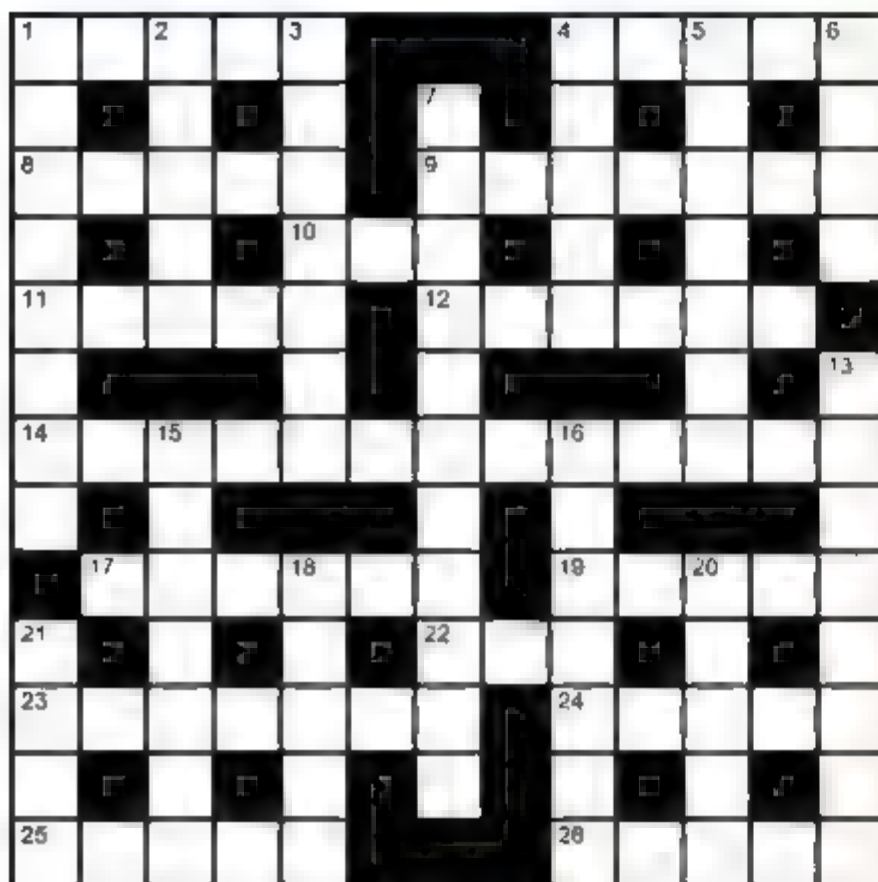
## THREE IDENTICAL STRANGERS

IN CINEMA NOW

This award-winning documentary follows the extraordinary story of three triplets, separated shortly after birth, who coincidentally find each other 19 years later. As the triplets learn more about the circumstances around their separation, the story gets darker, yet it provides a fascinating new look into the debate on nature versus nurture.

## BBC FOCUS CROSSWORD

### GIVE YOUR BRAIN A WORKOUT



### ACROSS

- 1 Shoot series, beginning with puritan (5)  
 4 Label American river (5)  
 8 Students accept first woman as equal (5)  
 9 Pain left university doctor in the past (7)  
 10 Ireland lost initial anger (3)  
 11 Frenchman spun tale for copper, say (5)  
 12 Element obtained from country without a hesitation (6)  
 14 Nove about who salutes state (3,5,5)  
 17 B-shop and a lieutenant in charge in Latvia, say (6)  
 19 Time to pair off an animal (5)  
 22 Newt is skilful without a head (3)  
 23 Terrible leech performing – rank (7)  
 24 Foreign character has a laugh about record (5)  
 25 Never worked as a writer (5)  
 26 Lake contains every last nest (5)

### DOWN

- 1 Demanding job, seasoning my one (4,4)  
 2 Fix hedge, removing front (5)  
 3 Girl gets one sign from Italian polymath (7)  
 4 Swollen tornado initially spreading mud around island (5)  
 5 Measured response in church (7)  
 6 Hardly fast food, by the sound of it (4)  
 7 Telescope in design for an epoch (11)  
 13 Mean ruse managed to obtain virtual tag (8)  
 15 Withstand conditions (7)  
 16 Comedian has a race with European power (7)  
 18 Head of teaching lied, fabricating Spanish accent (5)  
 20 Daily copy follows pressure put on Republican (5)  
 21 Fuel secures the German victory (4)

### ANSWERS

For the answers, visit [brlly/BBCFocusCW](http://brlly/BBCFocusCW)  
 Please be aware the website address is case-sensitive

NEXT MONTH IN

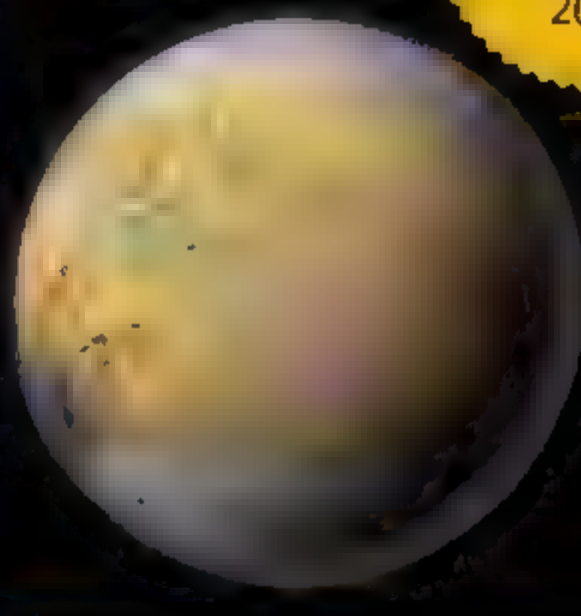
# FOCUS

## Stranger things

THE MOST MYSTERIOUS  
OBJECTS IN THE UNIVERSE

ON SALE

9 JANUARY  
2019

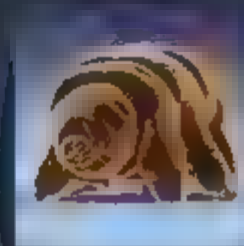


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flux

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## Dr Zoe Laughlin

This Yuletide, materials expert Dr Zoe Laughlin talks to Helen Pilcher about trifle, turkey and family traditions

Watch clips with Zoe from BBC Two's *The Big Life Fix: Inventing The Impossible* at [bit.ly/big\\_life\\_fix](http://bit.ly/big_life_fix)

### Where will you be for Christmas?

Back on the farm with Mum, Dad and everyone else who wants to come along. It's the one time my family will tolerate me making us play games. We'll be playing charades and lots of other games that we've invented over the years, like Twisted Knob, which is where we draw pictures of penises.

### Ahem... Moving on. Do you have any family traditions?

I'm a materials engineer, so I'm fascinated by making things and engaging with the world physically.

Mum and I both agree that the trifle is the king of Christmas puddings, but we can't agree on how to make it. So every year, we make one each. I like mine to have defined strata, like a geological formation, but my mum likes what can only be described as slop. We are opposite ends of the trifle spectrum.

### Can materials science help to create the perfect Christmas dinner?

Yes it can. We've shown how different materials can affect taste. If you're cooking tomatoes and you stir them with a metal spoon, they'll be more bitter than if you use a

wooden spoon. Copper makes things taste bitter, while gold can help things taste sweeter. You haven't lived until you've eaten mango ice cream off a gold spoon.

### Any tips on how to set the table, then?

Don't use silver cutlery – silver tastes horrible. You're much better off with stainless steel, or gold if you have it. I'd advise laying wooden plates. Eating off wood is really nice. It has this soft acoustic effect.

### What's on the menu?

One of the great pleasures is having turkey with crispy bacon, but be careful: moisture is the enemy of crispy bacon. I advise putting your bacon into a cold pan, then bringing it up to temperature on the hob slowly. This will evaporate out all the moisture and then, as it starts to cook, let all the fat render out. It will become an utter crisp delight and you can lay it across the top of the turkey.

### Trifle for pudding?

For me, trifle, but Christmas pudding is also allowed, as long as you think about what you flambé it with. Vodka is good because it catches fire more easily than brandy. And gin is also delicious – it leaves you with a citrus note that cuts through the thickness of the brandy butter.

### Do you have a favourite Christmassy material?

I have lots of favourites but let's say ice. It has all sorts of mental properties. Most things shrink when they go from liquid to solid, but water expands. That's why ice floats and as a result we have life in the oceans under the ice. It's also part of our physical experience of the seasons. It's a special type of pleasure when you step outside and there's ice on the puddles and you have the pleasure of cracking it. ❄️

**Dr Zoe Laughlin** is co-founder and director of the Institute of Making at University College London.

DISCOVER MORE



To listen to episodes of *The Life Scientific* with top scientists, visit [bit.ly/life\\_scientific](http://bit.ly/life_scientific)

NEXT ISSUE: STEPHEN REICHER

**"DON'T USE SILVER CUTLERY – SILVER TASTES HORRIBLE. YOU'RE MUCH BETTER OFF WITH STAINLESS STEEL"**



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